

**FRDA Report 126**  
**A Review of Natural Lodgepole Pine  
Regeneration in the Chilcotin**

by  
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## ABSTRACT

The re-establishment success of lodgepole pine (*Pinus contorta* var. *latifolia*) in the Very Dry Central Montane Spruce (MSd), the Very Dry Southern Sub-Boreal Spruce (SBSa), and the Sub-Boreal Spruce b (SBSb) subzones of the Chilcotin is investigated. Adequate stocking with well-spaced stems in the MSd does not appear to be guaranteed under present harvest and silvicultural techniques. Total stocking levels appear to be high in all three subzones. However, a detailed evaluation of stem numbers beyond which juvenile productivity is significantly reduced would enable a more accurate assessment of the extent of this problem. Literature pertaining to natural lodgepole pine regeneration and juvenile density management is summarized, and areas of future research are recommended.



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## INTRODUCTION

Lodgepole pine (*Pinus contorta* var. *latifolia*) accounts for roughly 50% of the total annual harvest from forests in the Cariboo Forest Region. In the past, openings in the Very Dry Central Montane Spruce (MSd), the Very Dry Southern Sub-Boreal Spruce (SBSa) and the Sub-Boreal Spruce b (SBSb)<sup>1</sup> subzones have been left to naturally regenerate with lodgepole pine. According to estimates by both industrial and government personnel, this management strategy has resulted in extensive stocking problems, including inadequate, patchy, and excessive stocking.

This review provides a summary of the stocking status and density of naturally regenerated, juvenile lodgepole pine in the MSd, SBSa and SBSb subzones of the Cariboo Forest Region. In addition, the re-establishment success, or failure, of lodgepole pine is assessed in relation to site characteristics and treatment history. A summary of literature on the natural regeneration of lodgepole pine is appended. Areas of further research required to resolve local lodgepole pine regeneration problems are recommended.

## THE STUDY AREA

Openings included in this review are situated in the MSd, SBSa and SBSb subzones. These subzones are found in the dry western half of the Cariboo Forest Region (Figure 1), an area commonly referred to as "the Chilcotin." The following description of the study area comes from Coupé and Yee.<sup>2</sup>

The MSd is an upper elevation subzone dominated by lodgepole pine and/or hybrid white spruce (*Picea glauca* x *engelmannii*) forests. This subzone extends east and north of the Coast Mountains, to the Fraser and Blackwater Rivers, respectively. It occurs at elevations of 1250-1550 m at the northern end of its range and from 1500 to 1750 m in the south. Topographically, this subzone is gentle to moderately steep.

The forests of the MSd have an almost continuous cover of mosses, scattered forbs and lichens. Shrubs, however, are sparse. Soil surface duff layers are thin (to 4 cm). Soils are strongly weathered and predominantly loamy to sandy loam in texture.

During the growing season, the climate in this subzone is very cool and dry. Winters are very cold. Snowpacks in the MSd are deeper than in the SBSa and SBSb and of longer duration (generally from October to early May).

The SBSa subzone, found at slightly lower elevations than the MSd, is forested primarily with lodgepole pine. However, white spruce (*Picea glauca*) can also be found on moist sites along drainage channels and along the perimeter of wetlands. This subzone covers the same extent as the MSd; it is bordered by the Fraser and Blackwater rivers and the Coast Mountains. It occurs at elevations of 850-1300 m toward the northern limit of its range and 1100-1500 m to the south. Much of this subzone is found over gently rolling topography.

Forests in the SBSa subzone grow under the coldest and driest climatic conditions of all Sub-Boreal Spruce subzones. The growing season is very cool and very dry. Winters are very cold with only light snowfall, beginning in mid-October. The thin snowpack generally lasts until late April. It is estimated that moisture deficits occur in the SBSa from June to September.

Consequently, the undergrowth in SBSa forests is sparse. The understory is dominated by pinegrass (*Calamagrostis rubescens*), dwarf shrubs, lichens and some feathermosses. The duff layer is thin, usually only 3 cm on mesic or drier sites. Exposed mineral soil is common. Soils are generally poorly developed and loamy to sandy loam in texture.

<sup>1</sup> The SBSa and SBSb subzones will become part of the new Sub-Boreal pine spruce (SBPS) zone as a result of provincial correlation presently in progress.

<sup>2</sup> Coupé, R.A. and A.R. Yee. [1990]. Identification and interpretation of ecosystems of the Cariboo Forest Region. B.C. Min. For., Res. Sect., Williams Lake, B.C. In press.



The SBSb subzone occurs in a 50-60 km wide, diagonal band running from Bonaparte Lake northward to the Blackwater River. This subzone occurs from 880 m in elevation to 1370 m at the southern end and 1060 m at the northern end of its range. The SBSb forests are dominated by hybrid white spruce and Douglas-fir (*Pseudotsuga menziesii*). The topography in this subzone is generally level to gently rolling. The undergrowth in SBSb forests, as in the SBSa, is dominated by pinegrass. Shrubs are sparse in this subzone. However, herbs and mosses are abundant. In general, soil surface duff layers range in thickness from 1 cm on dry sites to 6 cm on moist, sites. Soils vary in texture from loam to sandy loam.

Climatic conditions in the SBSb are intermediate. Although summers are warm, frost may occur at any time during the growing season. Annual rainfall averages 523 mm. June, July and August are the wettest months of the year. Winters are cold and dry. Snowpacks are generally thin and remain on the ground from late November through to early April.

In the study area, recommendations have been made by Coupé and Yee<sup>3</sup> about the post-harvest treatments most likely to ensure adequate natural regeneration of lodgepole pine. In the MSd subzone, where ground disturbance from harvesting operations does not provide an adequate number or distribution of favourable growing spots, scarification is the technique most often used to reduce duff thickness to less than 2 cm. Coupé and Yee suggest that sufficient disturbance can result from summer logging. If a site is winter-logged, however, drag scarification is usually required. Coupé and Yee further cite operational experience which indicates that stocking voids will result in this subzone if mineral soil is not exposed. On the other hand, they suggest that intensive scarification in the SBSa may result in the more common problem of overstocked, repressed stands with greater than 20 000 stems per hectare. In the SBSb subzone, no site disturbance, pile and burn, or a light slashburn are the recommended approaches. Site treatment is considered to be particularly important in the northern portion of the SBSb since duff thicknesses often exceed 2 cm.

## METHODS

This review of natural lodgepole pine regeneration in the Chilcotin is based on information obtained from several sources: an extensive literature search; the Ministry of Forests History Records for the MSd, SBSa and SBSb subzones in the Cariboo Forest Region; unpublished data collected for the Cariboo Forest Region, Research Section, by R.Meister during the 1986 field season; a February 23, 1987 meeting of foresters from both government and industry held to identify local regeneration problems; and the unpublished "Identification and Interpretation of Ecosystems of the Cariboo Forest Region."

An extensive literature search was conducted for information about the establishment and stocking control of natural lodgepole pine regeneration. Particular attention was paid to recommendations on specific silvicultural techniques which appear to favour the natural re-establishment of acceptable stands of lodgepole pine.

Site characteristics (aspect, gradient, elevation and site class), treatment, stocking status and numbers (well-spaced and total) of stems per hectare were collated from the Ministry of Forests History Records for each subzone. An attempt was made to find correlations between site characteristics and/or treatments and stocking status or density. Only those openings reporting both well-spaced and total stems per hectare were used. This stocking information was generally unavailable before 1980. Data from a total of 357 openings were assessed, including information from 17 openings in the MSd, 152 in the SBSa, and 188 in the SBSb.

Additional site and stocking data were also obtained from records of a field survey by R. Meister (B.C. Ministry of Forests, Res. Sect., pers. comm., Feb. 1987). Thirteen openings were surveyed in the MSd and 10 in the SBSb. The data included similar site characteristics to those cited above, as well as an assessment of moisture regime; percent humus cover, dead wood, rock and mineral soil; an estimate of percent mineral soil exposure in the year following logging; present vegetative cover; and duff thickness. An attempt was made to correlate the site data with well-spaced and total stems per hectare, as well as with overstocking at 2000 and 10 000 stems per hectare.

<sup>3</sup> Coupé and Yee, [1990].

## RESULTS

Considerable information regarding the natural establishment of lodgepole pine is available in the literature. Silvicultural techniques that promote the re-establishment of this species on specific sites as well as controlling the distribution of germinants in an opening are recommended. In contrast, little information appears to be available on stocking control in juvenile stands less than 15 years of age. The information which is available has been summarized in Appendix 1 of this report. Readers are encouraged to refer to the original sources for greater detail.

The results of past silvicultural practices, expressed as area stocked, not-stocked, and total stems per hectare, are summarized in Table 1. In the SBSa and SBSb subzones, 79 and 88% of the openings left to naturally regenerate with lodgepole pine are stocked (i.e., have greater than 700 well-spaced, acceptable stems per hectare). However, the chance of achieving satisfactory restocking in the MSd using present techniques is only 52%. It should be noted that the figures calculated for the MSd are based on a very small sample. At the time of this review, stocking information was only available for 17 out of a total of 34 openings. Nevertheless, since harvesting operations continue to move to higher elevations in the Chilcotin, these data do suggest that a more detailed investigation should be conducted into the suitability of regeneration strategies used in the MSd.

When post-logging treatment as well as season of logging and year of disturbance were reviewed in relation to stocking status, no correlation was found. Elevation, aspect, slope and site class also appeared to have no significant influence on regeneration success within each of the three subzones in the study area.

Further, an investigation of the more detailed site-specific data provided through R. Meister's 1986 field survey, for the MSd and SBSa subzones, again revealed no correlations between elevation, aspect, slope, season of logging, year of disturbance or post-logging treatment, and either well-spaced or total stems per hectare. Estimates of percent mineral soil exposed in the first year of disturbance (either through logging or site preparation), percent vegetation cover, and average duff thickness were also compared to total and well-spaced stems per hectare. With the exception of average duff thickness no correlations were found. A significant, positive correlation at 95% was found between average duff thickness and both total and well-spaced stems (Appendix 2). In the MSd, the average duff thickness on NSR (not satisfactorily restocked) sites was 4.5 cm and on SR (satisfactorily restocked) sites it was 3.5 cm. In the SBSa the average duff thickness on NSR sites was 4.2 cm as compared to 3.0 cm on SR sites.

## DISCUSSION

The lack of correlation between site characteristics and stocking observed in this review supports the findings of other researchers (Appendix 1). It is generally agreed that it is the complex interaction between environmental variables, rather than a single factor, which influences stocking. Further, since the classification of sites into subzones should reduce environmental variability within each group of openings reviewed, it is likely that comparisons of these same variables between, rather than within, subzones would be more significant. The elapsed time between disturbance and survey was also not found to have a consistent effect on stocking status, contrary to correlations described in the literature.

The correlation found between average duff thickness and both total and well-spaced stems in the MSd and SBSa data provided by Meister is also supported by work cited in the literature regarding both seedbed disturbance and moisture availability. That is, duff disturbance favours increased stocking by providing improved seedbed conditions, including increased available moisture. The lack of correlation between exposed mineral soil and stocking, even though a relationship exists between duff thickness and stocking, may be due to the fact that estimates were made several years after treatment. As they were not actual measurements they may not be entirely accurate.

TABLE 1. The extent of various stocking levels in openings naturally regenerated with lodgepole pine, in the MSd, SBSa and SBSb subzones, in the Cariboo Forest Region (FRDA 3.19)

|                            | MSd <sup>a</sup> | SBSa <sup>b</sup> | SBSb <sup>c</sup> | Total  |
|----------------------------|------------------|-------------------|-------------------|--------|
| No. openings summarized    | 17               | 152               | 188               | 357    |
| Total area (ha) summarized | 1098             | 10 428            | 9 835             | 21 361 |
| NSR                        |                  |                   |                   |        |
| ha                         | 529              | 2 160             | 1 173             | 3 862  |
| %                          | 48               | 21                | 12                | 18     |
| SR                         |                  |                   |                   |        |
| ha                         | 569              | 8 268             | 8 662             | 17 499 |
| %                          | 52               | 79                | 88                | 82     |
| >10 000 sph <sup>d</sup>   |                  |                   |                   |        |
| ha                         | 103              | 443               | 356               | 902    |
| %                          | 9                | 4                 | 4                 | 4      |
| > 2 000 sph                |                  |                   |                   |        |
| ha                         | 674              | 7 429             | 7 892             | 15 995 |
| %                          | 61               | 71                | 80                | 75     |

a Data based on 50% of the total MSd opening area in the Cariboo Forest Region.

b Data based on 30% of the total SBSa opening area in the Cariboo Forest Region.

c Data based on 25% of the total SBSb opening area in the Cariboo Forest Region.

d Stems per hectare.

It should be noted that considerable overlap exists in the ranges of duff thickness recorded in all stocking categories and that the averages obtained from this data should only be used to provide some direction for future field work. It does, however, appear that a range of duff thicknesses exists within which stocking will be adequate but not overly dense. Reductions in duff thickness below this range could result in overstocking. Further, site preparation techniques, or the lack thereof, which result in duff thicknesses greater than the acceptable range may not provide suitable seedbed conditions for adequate germination and survival. Work cited in the literature seems to indicate that reductions in stocking can be expected once duff thickness exceeds 2-3 cm and that overzealous site preparation will lead to overstocking.

According to Meister's data, the acceptable range in the MSd and SBSa appears to be between 3 and 4 cm. Thicknesses below 3 cm were generally associated with overstocking and those above were generally NSR. These data further indicate that the regional recommendation of reductions in duff thickness to 2 cm may result in overstocking in the study area. However, the reader is also cautioned that the values of 3 and 4 cm were derived from an average of a small number of samples and should simply be used to identify future research needs. Field work should be carried out in each subzone to more accurately define the range of duff thicknesses within which appropriate stocking levels are achieved. Certainly the degree of site disturbance is a variable which should be monitored in any future comparisons of the suitability of various silvicultural techniques for the natural re-establishment of lodgepole pine.

Total trees compared with well-spaced stems in the openings surveyed by Meister (1986) show that total stems per hectare rarely fell below the minimum stocking standard of 700 well-spaced, acceptable stems per hectare even when sites were classified as NSR. This implies patchy stocking conditions. The problem of patchy regeneration was also described by local foresters, at the meeting held on February 23, 1987, as being next in priority to overstocking as a problem to be addressed in the field. The distribution of suitable seedbed produced by various site preparation techniques should be investigated to determine which methods are most likely to cause patchy stocking.

Silvicultural techniques most commonly applied in the MSd, SBSa and SBSb subzones to provide suitable seedbed for lodgepole pine establishment are chain drag scarification, occasional spot burning in the SBSb, and, most commonly, no treatment at all. As mentioned previously, based on the data available, no significant differences in stocking could be found between treatment types. This is likely a function of the data and reassessments should be made in the field. It is, however, also consistent with

the highly variable results of site preparation, in terms of natural regeneration success, reported in the literature.

As shown by the openings considered in this review, the re-establishment of lodgepole pine in the numbers required for sites to be classified as stocked is apparently not a serious problem in the SBSa and b subzones of the Chilcotin. However, the reverse is true in the MSd, where adequate stocking does not appear to be guaranteed. The natural re-establishment of lodgepole pine on these higher elevation sites may be influenced by differences in cone serotiny, seed viability, or climatic conditions. It is in this area that further research into the natural re-establishment of lodgepole pine in clearcuts appears to be most necessary.

In regard to total numbers of stems, of the openings reviewed, less than 10% in the MSd and 5% in the SBSa and SBSb are overstocked according to the present criteria of 10 000 total stems per hectare. However, these proportions are drastically altered if the suggested level of 2000 total stems per hectare (as per February 23, 1987, meeting at Williams Lake) is considered. If a stand having greater than 2000 total stems per hectare is classified as overstocked; 61, 71 and 80% of all naturally regenerated lodgepole pine openings reviewed in the MSd, SBSa and SBSb respectively are overstocked. This indicates that if the maximum acceptable stocking density for a productive stand is only 2000 total stems per hectare, overstocking would in fact be a major problem, particularly in the SBSa and SBSb. Otherwise, if 10 000 stems per hectare is an acceptable limit there is apparently no particular problem. Consequently, the stocking level at which productivity is significantly reduced in specific subzones should be thoroughly investigated. The determination of this stocking level is of particular importance as a FRDA research priority, since it is also used to determine which juvenile pine stands can be rehabilitated as "backlog" versus "intensive."

## CONCLUSIONS

From the information presently available, lodgepole pine does not appear to re-establish consistently on clearcut sites in the MSd, SBSa and SBSb subzones at an acceptable number of well-spaced stems per hectare.

The successful re-establishment of lodgepole pine in openings in the MSd is of particular concern. In this area, 48% of the openings are classified as NSR. The causes of past regeneration failure and the development of appropriate silvicultural strategies should be given a high research priority to ensure that this trend does not continue, particularly since the rate of harvest in this subzone is increasing.

The second major problem related to naturally regenerated lodgepole pine in the study area appears to be that of over-stocking. The first issue that must be addressed to resolve this problem is the definition of the number of stems per hectare beyond which juvenile productivity is significantly reduced. Once this stocking level has been defined, further research is required to determine which silvicultural techniques are most successful in re-establishing acceptable numbers of well-spaced lodgepole pine stems.

The findings of this review are preliminary and require field verification. However, recommendations can be made in several areas of investigation, specifically concerning natural lodgepole pine regeneration problems identified in the study area.

## RECOMMENDATIONS

The following recommendations for future research are based on the findings of this review.

1. Cone serotiny and seed viability should be described throughout the Chilcotin in relation to location, stand age, site characteristics, and, in the case of seed viability, over time. Regeneration techniques should then be prescribed accordingly. This is particularly important in the MSd subzone where natural regeneration failure appears to be more prominent.
2. Relationships between post-harvest treatment delay and regeneration success and/or juvenile stand density should be determined for specific subzones in the Chilcotin. These results should control the scheduling of site preparation following harvest.
3. The degree of disturbance required to achieve the desired number of well-distributed stems on specific sites should be determined.
4. The stocking density beyond which significant reductions in juvenile growth occur in all three subzones must be determined. This will allow a full evaluation of the extent of over-stocking problems and the establishment of treatment priorities.

The resolution of these issues in the Chilcotin will assist foresters in prescribing management techniques which promote the successful, natural re-establishment of lodgepole pine at acceptable densities.



## APPENDIX 1. Natural regeneration of lodgepole pine: a literature review

Lodgepole pine occurs throughout most of British Columbia. This species can be found at elevations ranging from submontane to subalpine and in hygrotopes varying from very wet to very dry (Krajina *et al.* 1982). Even though moderately drought resistant, lodgepole pine does appear to exhibit its best development on mesic north and east slopes (Lotan and Perry 1983). In relation to its associates, lodgepole pine requires more moisture than the other species (Satterlund 1975). According to Krajina *et al.* (1982), lodgepole pine occurs on sites having poor to moderate nutrient regimes. The ability of this species to occupy the least fertile sites may be a result of extremely low nutrient requirements, or of its ability to extract nutrients unavailable to other species (Lotan and Perry 1983). On nutrient-rich sites other species appear to have a competitive advantage over lodgepole pine. This species is most often shade-intolerant. Lodgepole pine ranks mid-way among its associated tree species in temperature sensitivity. This is demonstrated by a general decrease in seedling height with increasing elevation (Lotan and Perry 1983). This same relationship does not exist with root growth or cone production. Lodgepole pine has moderate to high frost tolerance (Krajina *et al.* 1982), with very young seedlings being the most resistant (Lotan and Perry 1983).

### REGENERATION CHARACTERISTICS

Lodgepole pine is generally considered to be a prolific seed producer with good crops occurring every 1-3 years (Lotan *et al.* 1985). Regular seed production is not, however, always guaranteed. Lotan and Perry (1983) cite intervals of 4 years between cone crops on sites at 2800 m in northwestern Wyoming. Generally, a greater percentage of the seed produced in good crop years is sound or viable as compared to poor crop years (Alexander 1974b). The definition of a "good" crop is, however, fairly subjective.

Cone production in lodgepole pine begins at an early age, generally at 5-10 years (USDA Forest Service 1974). In more densely stocked stands this minimum age increases to 15 or 20 years (Alexander 1974b). Stand density not only influences the age at which seed is produced but also the volume produced (Lotan and Perry 1983). Lotan and Perry (1983) cite studies in which cone counts range from 0 to 9000 on suppressed and open grown trees respectively, and from a few hundred to a few thousand on codominant and mature dominant trees respectively. Similarly, seed yield varies from tree to tree and cone to cone. Provided that an adequate supply of pollen is available, open grown, dominant trees produce more seeds per cone than do suppressed trees.

The dissemination of seed, and consequently the regeneration of lodgepole pine, is influenced by cone habit. Lodgepole pine cones can be serotinous or non-serotinous. In serotinous cones, the cone scales are sealed by a resin bond. The melting point of this resin seal is 45 to 50°C (USDA Forest Service 1974). In unlogged stands this bond is broken by fire. Once the bond is broken the cone scales dry out and open, as do non-serotinous cones on ripening. Seed is then disseminated by wind and/or gravity. It has been found that the dispersal of sufficient seed from open-coned or non-serotinous stands to restock an adjacent opening adequately, rarely occurs beyond 60 m from the timber edge (Lotan and Perry 1983).

Seed in serotinous cones remains viable for many years (Pfister and Daubenmire 1975). Lotan (1975) cites work which indicates that no significant reduction occurs in seed viability with cone age, and that serotinous cones can remain attached to the tree for decades. Hellum (1983) states that most cones on trees surveyed in Alberta persist for roughly 15 years, but very few remain attached for more than 30 years regardless of site, age, aspect or stand density. The ability of lodgepole pine to retain cones produced over many years, and to maintain seed viability, generally results in large quantities of seed available for natural regeneration after disturbance.

Serotiny can vary among cones on an individual tree, among trees in a stand, and between stands, as can the viable seed content of individual cones. As a result of this variability, cone serotiny and seed content must be determined for each stand prior to the prescription of specific silvicultural treatments (Alexander 1974b). Alexander (1974b) classifies individual trees as having closed cones if 90% or more are serotinous and open cones if less than 10% are serotinous; and as being intermediate if less than 90 but more than 10% of cones are serotinous. Armit (1966) cites work in Alberta and elsewhere which

indicates that the proportion of trees in a stand having closed cones varies with age. In the stands surveyed, the majority of trees under 50-60 years of age (less than 30 years according to Lotan [1975] and Wheeler and Critchfield [1985]) bore non-serotinous cones, while cones on more mature trees were primarily serotinous. Clark (1974) found some correlation between cone habit and site class. On the highest quality sites trees had mostly serotinous cones, while on the poorest sites cones were largely non-serotinous. Wheeler and Critchfield (1985) cite stand-initiating disturbance as the major cause of between-stand variation in cone serotiny, with fire-initiated stands being dominated by trees with closed cones. Latitude may also influence cone habit. Ferdinand (1983) states that north of 53° latitude lodgepole pine cones appear to be less serotinous than those in stands to the south.

Once dispersed, seed overwinters and germinates the following spring (Alexander 1974b). Some seed may not germinate until the second spring as a result of occasional embryo dormancy (Pfister and Daubenmire 1975). Prior to germination, a portion of this seed may be consumed by small mammals and birds (Lotan and Perry 1983). The amount consumed is unknown but it is thought to be considerable (Alexander 1974b; Lotan and Perry 1983).

Dispersed seed does not generally remain viable in large numbers for more than 1 year (Lotan *et al.* 1985). The germination of this viable lodgepole pine seed under field conditions is highly variable and depends on climatic and seedbed conditions (Lotan and Perry 1983). Lodgepole pine seed germinates best at temperatures of 21-27° C but is poor at temperatures less than 15°C (Lotan and Perry 1983). Lotan and Perry (1983) cite several studies which have found that maximum germination occurs immediately after snowmelt, when soil moisture is high and temperatures are favourable.

Germination is best on mineral soil or disturbed duff (USDA Forest Service 1974) since these seedbeds provide more stable moisture conditions than do organic seedbeds (Alexander 1974b), which tend to dry out more quickly (Lotan and Perry 1983). Acceptable germination has also been found on disturbed or undisturbed duff which is not thicker than 2.5 cm, especially on moist sites (Lotan *et al.* 1985). Soil texture also influences moisture availability. Lotan and Perry (1983) cite work which indicates that germination is reduced on heavier textured soils as a result of low moisture availability. Droughty conditions can hamper not only initial germination, but also the subsequent survival of newly germinated seedlings. Slight shading from light slash or residual stems can reduce excessive heating and drying (Alexander 1974b).

Lotan and Perry (1983) suggest allelopathic influences as possible causes of reduced germination levels in some situations. They cite almost total inhibition of lodgepole pine seed germination on seedbeds dominated by fresh or partly decomposed Engelmann spruce litter. This effect was apparently removed by heating the litter.

Once seed has germinated, seedling survival is not guaranteed. This again depends on environmental and biotic conditions on-site. Drought is cited as the most common cause of seedling mortality during the first year (Lotan and Perry 1983). The rate at which root development takes place, and consequently the ability to obtain moisture during this time, largely determines initial survival (Alexander 1974b). As mentioned previously, seedbed conditions influence droughtiness. High rates of mortality have been observed on alluvial sands which have low water holding capacities (Lotan and Perry 1983). As the silt plus clay content increases in such sandy soils, so does first-year survival. Seedlings established in duff and litter, which dry out quickly, are also susceptible to high rates of mortality (Smithers 1961). However, well-decomposed organic matter such as humus may actually retain more moisture than mineral soil (Lotan and Perry 1983). Drought-related mortality losses generally decline after the first growing season (Alexander 1974b). In addition to drought, excessive moisture also reduces the chances of seedling survival because of reduced soil aeration and, consequently, restricted root development (Smithers 1961).

Until a protective layer of bark begins to develop, newly germinated seedlings are also susceptible to heat induced mortality, particularly on sites with poor water-retention characteristics. Death of tissue occurs at 50°C. However, even though soil surface temperatures commonly exceed 60°C, tree seedlings are generally able to maintain temperatures below the lethal level (Lotan and Perry 1983). The probability of heat mortality increases with decreasing water availability; as moisture is depleted and transpiration levels decrease, seedlings are less able to dissipate heat efficiently (Lotan and Perry 1983). At the other extreme, seedlings are also susceptible to frost damage, particularly during the first year (Alexander 1974b). Seedlings can, however, become somewhat frost resistant through several near-freezing nights before the first frost (Lotan and Perry 1983).

Other losses of newly germinated seedlings can occur as a result of damping-off fungi, particularly if the seedbed remains moist for long periods (Alexander 1974b). Lodgepole pine is less susceptible to this fungus than other species so losses are generally minimal (Lotan and Perry 1983). Snowmold fungus can also be a problem when snowmelt is retarded (Alexander 1974b), as can predation by rodents, especially on freshly burned openings (Lotan and Perry 1983).

Lodgepole pine is generally considered to be a poor competitor. During seedling establishment, grass is generally the most severe competitor of any vegetation type, particularly if a sod cover is formed before seedling establishment (Lotan and Perry 1983). The presence of grass often means the presence of cattle. Cattle do not usually eat lodgepole pine seedlings intentionally (Lotan and Perry 1983), but do trample and incidentally eat seedlings, thus increasing mortality.

Rarely does any single environmental or biotic factor control the success of natural regeneration. Consequently, the interrelationships between all factors influencing seedling establishment must be considered before the most appropriate silvicultural techniques can be prescribed.

## REGENERATION MANAGEMENT

The literature contains repeated references to several conditions which must be met to achieve successful, natural regeneration of lodgepole pine on a site. As summarized by Cochran (1973), these conditions include:

- the availability of an adequate supply of evenly distributed seed on the site;
- warm and moist soil surface conditions, to promote germination;
- moderate variation in air and soil surface temperatures;
- the ability of seedlings to withstand summer drought; and,
- minimal frost heaving during seedling establishment.

Many field trials have been established to determine which management strategies best provide these conditions.

Clearcut, seed-tree, shelterwood or group-selection harvesting patterns can all provide acceptable conditions for the re-establishment of lodgepole pine (Lotan and Perry 1983). However, clearcutting is the most common method. Reasons for this general adoption of the clearcut method include: the relative shade intolerance of lodgepole pine; the widespread occurrence of dwarf mistletoe in mature stands and the rapid reinfection of residual stems after partial cutting; windthrow; inadequate growth response of mature residuals; the threat of mountain pine beetle attack; and cost considerations (Lotan and Perry 1983; Vyse and Navratil 1985).

Regardless of the harvest method used, successful natural regeneration of lodgepole pine depends on the even distribution of adequate numbers of seed over the area cut. This becomes paramount in clearcut areas where seed left on-site during harvesting, or available through wind-dispersal from adjacent stands, is the only source of future crops (Lotan 1975). Clearcutting does, however, result in a greater degree of site disturbance than other techniques, thereby increasing the amount of suitable seedbed (Smithers 1961). Season of logging may also influence the degree of site disturbance and consequently the amount of favourable seedbed. Clark (1974) estimates that summer logging results in mineral soil exposure over 26% of an area, as compared to 12% as a result of winter logging. However, the reverse was noted in terms of "disturbed" seedbed (seedbed in which the surface organic layer has been disturbed but not removed). Clark (1974) suggests that since disturbed seedbed provides only a slightly less favourable environment for lodgepole pine establishment, the amount of favourable seedbed produced during both seasons of logging is roughly the same. He does, however, note that stocking densities are generally not as high on disturbed seedbeds as they are on exposed mineral soil.

The size of clearcut likely to regenerate naturally also depends on cone serotiny (Alexander 1974a). As mentioned previously, seed dispersal from stands with non-serotinous or intermediate cone habit becomes inadequate to achieve acceptable stocking at distances greater than 60 m from the stand's edge. In such situations, the maximum size of opening likely to restock naturally is four to five tree heights in width (Alexander and Edminster 1981). Lodgepole pine in the study area is generally

considered to have a closed-cone habit (D. Wallinger, B.C. Ministry of Forests, Silv. Br., pers. comm., Feb. 1987). Consequently, in most clearcut areas to be regenerated naturally, reliance is placed on seed from serotinous cones in logging slash. In this case, the opportunity for successful regeneration occurs once (Lotan 1975).

Several techniques are described in the literature for determining whether adequate numbers of seed, contained in serotinous cones, are available on a site to achieve the desired stocking levels. Lotan and Perry (1983) developed regression equations to estimate the number of cones available on sites in the Rocky Mountains. These estimates are based on sample cone counts, tree diameter, crown ratio and age. Though reliable, this technique is costly to apply. Subsequently, simpler equations were developed based on a count of trees bearing serotinous cones, average diameter and average age. Though simpler, they found this method to be less reliable.

The number of cones estimated by both techniques is used to calculate the amount of available seed through estimates of viable seeds per cone (Lotan 1975). Lotan and Perry (1983) recommend that the number of seeds per cone should be obtained through actual seed counts on or adjacent to the area to be regenerated. They further remind potential users that not all seeds are filled or viable. Consequently, cutting tests should also be carried out on samples of seed from all openings.

Most often, estimates of seed availability are made after logging. Such estimates of seed supply are advantageous since many cones counted before disturbance may be buried, crushed, or removed from the site during logging (Vyse and Navratil 1985). Clark (1974) suggests that 50% or more of the available cones may be lost if tops are skidded to landings. A procedure for estimating post-logging seed availability has been developed by Glen (1979). It involves counting the total number of cones and the proportion of these cones lying on acceptable seedbed. He makes further assumptions regarding the number of cones, with various viable seed contents, required on a site to produce desired stocking levels. He suggests that 100 viable seeds are required to produce a single 5-year-old seedling, on prepared sites. Lotan and Perry (1983) suggest larger ratios than this ranging from 300:1 on well-prepared, cool, moist sites with low competition to 15 000:1 on hot, droughty sites with heavy competition. According to Ferdinand (1983), the Alberta Forest Service considers a minimum of 25 000 evenly distributed serotinous cones per hectare adequate on dry sites to achieve 80% stocking. They recommend increased numbers of cones on moist sites. The actual seed:seedling ratio required to regenerate a site successfully varies with seedbed treatment, ecosystem and environmental conditions following seed dispersal (Lotan and Perry 1983). The development of local ratios based on seed-trap and survival data is generally recommended throughout the literature.

Often, even though adequate supplies of seed are available, this seed may not be evenly distributed over an opening, nor may the seedbed be suitable. Commonly, some form of seedbed treatment and slash redistribution is necessary to obtain adequate stocking (Ackerman 1962, 1966). The timing of any such treatment is important since most seed contained in slash is released during the first year (Alexander 1966). Many studies have been undertaken to determine which techniques provide the greatest improvement to seedbed conditions and cone distribution. These have included broadcast burning; piling and burning; logging and scattering; and scarification, among others.

Broadcast burning reduces the fire hazard, enhances cone opening and eliminates many damaging agents. Results, however, have been highly variable. To a large extent, the amount and distribution of suitable seedbed following burning depends on moisture conditions at the time of burning and the depth of the duff layer (Lotan and Perry 1983). The timing of broadcast burning after harvesting will also influence regeneration success. If burning is delayed, seed shed before this treatment, as well as any newly established germinants, will be destroyed (Wilford 1984). Seed losses of more than 90% have been reported (Lotan *et al.* 1985). Consequently, Wilford (1984) recommends that even though fire has played an important role in the development of Chilcotin pine stands, broadcast burning may not be the best way to improve seedbed conditions.

Feller (1982) summarizes the many differing views about the effects of burning on lodgepole pine regeneration. These range from beneficial to detrimental. He lists detrimental effects as including the destruction of seed and new germinants, loss of shade, and soil damage in the case of severe burns. Lotan *et al.* (1985) report soil damage only under large piles of slash, which they suggest should not cover more than 25% of the treated area. Feller (1982) concludes that, in general, successful natural regeneration of lodgepole pine can be achieved through burning, but that this species prefers mineral rather than burnt organic seedbeds. Lotan and Perry (1977) found that burning on Douglas-fir/pinegrass

sites was unacceptable in terms of lodgepole pine regeneration, since this technique stimulated grass competition. Smithers (1961) recommends that if a site is to be burned, clearcut strips should be no more than 100 m wide to increase the chance of seeding from adjacent stands.

When pile and burn techniques are used, slash should not be piled until temperatures required to break the resin bonds have been exceeded. Furthermore, piling should not be delayed past the first autumn after logging since, by spring of the following year, released seed will have germinated (Lotan and Perry 1983). Benson (1982) found piling and burning to produce the best results on sites in Wyoming when compared to broadcast burning, residue removal and chip and spread. Five years after treatment, Benson (1982) found stocking in the study area to be approximately 6500 stems per hectare, with 66% of the milacre plots stocked. Lotan and Perry (1976) observed similar results in an earlier comparison of identical site treatments. Mineral seedbed exposed during the piling process provides suitable seedbed. However, this technique may also increase erosion, remove protective cover, result in the destruction of seed contained in the piles, and result in nutrients being concentrated in the slash (Lotan and Perry 1983). Piling and burning does, however, provide considerable reductions in vegetative competition when compared to techniques such as logging and scattering (Kovalchik and Blake 1972).

Lopping and scattering has been found to work well where distribution of as many stored seeds as possible is required (Lotan and Perry 1983). However, Armit (1966) cites work in Alberta which indicates that, without some scarification, lopping and scattering of slash is not an effective technique. Kovalchik and Blake (1972) similarly report that little proper seedbed is exposed by this technique. They also point out that an immense quantity of seed can be made available through the chopping and distribution of slash. Smithers (1961) recommended that once slash has been lopped, scarification should be carried out with a coarsely toothed blade. With this method, larger slash could be piled and burned while finer cone-bearing slash would pass through the teeth and be distributed over the site. The use of a toothed dozer blade also reduces deep soil disturbance (Tackle 1954). The light slash cover resulting from this technique reduces temperature extremes, helps maintain soil moisture, and offers some protection against frost heaving (Lotan and Perry 1983). These benefits may be of particular importance to seedling germination and survival on harsh sites (Lotan and Perry 1983). Bates *et al.* (1929) suggest that light slash left on-site may be beneficial on south aspects. The benefits obtained by slash cover become negligible after roughly 2-3 years, due to rapid needle loss at this time (Cochran 1973).

Drag scarification is the most extensively used method of improving seedbed condition and cone distribution in British Columbia (Forest Research Council 1983). Glen (1979) provides recommendations for the most appropriate drag scarification techniques depending on cone and seedbed distribution. Smithers (1961) recommends that roughly 20% of the cutover area should be exposed mineral soil after scarification. In fresh slash containing adequate numbers of cones, Thompson (1978) found that approximately 60% mineral soil plus disturbed seedbed was required to obtain 50% stocking, at 1200 stems per hectare, within 4 years. Further, that if scarification was delayed for 1 year, 80-85% of the site must be disturbed (Thompson 1978). Site disturbance objectives in Alberta are cited as 60-65% mineral soil exposure, measured by the milacre plot method (Ferdinand 1983).

In addition to providing suitable seedbed, drag scarification also crushes cone-bearing slash, resulting in a larger proportion of cones located within 15 cm of the ground surface (Forest Research Council 1983). It is within this zone that the temperatures of 45-50°C required to break cone resin bonds occur (Forest Research Council 1983). Stanek (1966) cites work indicating that if excessive crushing occurs and cones are placed directly on the ground they may absorb too much moisture and remain closed, or on sandy soils may become covered with sand as a result of raindrop impact on the soil surface. In general, however, the literature cites promising but variable regeneration results following drag scarification.

The timing of scarification appears to play an important role in subsequent stocking density. Crossley (1976) found that immediate scarification of sites resulted in approximately 32 000 stems per hectare at the end of ingress; whereas when scarification was delayed, average stocking densities were 12 000 stems per hectare. He further found that ingress lasted from 9 to 15 years, peaking in the third year following scarification. When scarification was delayed for more than 1 year ingress became more erratic over time (Crossley 1976). If scarification is delayed beyond seed release then a portion of this seed will be buried during treatment (Thompson 1978). In Alberta, Ferdinand (1983) found that north of 53° latitude, where cones appear to be less serotinous, a scarification delay of greater than 1 year caused regeneration failure as a result of seed loss. However, in the southern part of the province scarification could be delayed until the second year (Ferdinand 1983).

An assessment of the success of various silvicultural treatments depends on the time between site preparation and the regeneration survey. Near Prince George, Glen and Ackerman (1978) found that 3.6 years after drag scarification, 36% of the sites sampled were stocked, whereas 5.6 years after treatment, stocking had increased to 73%. They concluded that surveys should be delayed until at least the fifth growing season after site treatment. Thompson (1978) found lodgepole pine ingress to continue for 15 years in the Nelson Forest Region. Johnstone (1976) found ingress occurred for up to 11 growing seasons after scarification in a study near Hinton, Alberta. Linfield and Hellum (1985) investigated ingress on 41 scarified sites in Alberta, in relation to site quality as defined by moisture regime. They found that on good sites stocking reached 80% before the seventh year regeneration survey. On poor sites ingress continued beyond the seventh year. However, stocking levels were unacceptable. Ingress had a significant effect on stocking status between the 7th and 10th-year surveys on marginal sites.

Initial regeneration density can be controlled through delayed site preparation and by limiting the proportion of the site disturbed (Johnstone 1976; Glen and Ackerman 1978). Lotan and Perry (1977) suggest that where overstocking problems are anticipated no site preparation may be a useful density control technique. However, regardless of disturbance (i.e., whether by fire, logging, or site preparation) studies in Alberta indicate that over 80% of the naturally regenerated lodgepole pine occurs in clumpy patterns (Bella 1983). The degree of clumping and overstocking depends on the viable seed supply, seedbed, and climatic conditions, with moisture being the most important single climatic variable (Bella 1983).

## DENSITY MANAGEMENT IN JUVENILE STANDS

A recent study by the Forest Research Council of British Columbia (1983) suggests that overstocking of naturally regenerated lodgepole pine is a more serious problem than insufficient stocking. It further reiterates that this overstocking may be a result of either wildfire or of past logging and site preparation practices. All further discussions of overstocking in this paper will be in relation to the latter form of stand initiation. The problem of overstocking is compounded by lodgepole pine's inability to thin itself (Flewelling and Drew 1985). Furthermore, in spite of high levels of natural mortality in overstocked stands, these stands tend to remain dense regardless of site quality, a variable to which lodgepole pine establishment does not appear to be related (Johnstone 1985).

A survey of the literature regarding density control in lodgepole pine stands indicates that the majority of work has been carried out in stands over 30 years of age. Those studies completed in younger stands (less than 30 years of age) form the basis of the following discussion.

Dense stocking reduces stand and individual tree growth (Johnstone 1981b). Flewelling and Drew (1985) state that stands with densities greater than 4500 stems per hectare will not produce merchantable volumes at 90 years. Smithers (1961) and Alexander (1974b) suggest that if a stand contains more than 6250 stems per hectare at 10-20 years of age, it should be thinned to 3750 to maximize growth. Smithers (1957) recommends that such thinning should be carried out only on the best sites. Final densities should be determined at age 30.

When stand densities are reduced at an early age, growth is stimulated, especially diameter growth (Alexander 1965; Dahms 1971; Johnstone 1985). The magnitude of diameter growth response to release depends largely on initial tree size; the larger the initial size the greater the response (Smithers 1957; Johnstone 1985). Diameter growth response is also affected by the degree of density reduction. A 1983 study by Johnstone, in which stand density in young lodgepole pine was reduced from 7907 stems per hectare to 494 stems per hectare, showed increases in mean diameter and post-treatment diameter of 89 and 131%, respectively.

Height growth responses to reductions in stand density are less dramatic (Johnstone 1985). Height growth is, however, greatly influenced by stand density (Flewelling and Drew 1985). Research results regarding height growth response vary from none (Dahms 1971) to some in very young stands (less than 5 years of age according to Alexander [1965]) on poorer sites (Johnstone 1985).

Total stand volume at maturity can be increased by reducing the density of young overstocked stands that have not yet become suppressed (Johnstone 1985). Additionally, equal volumes of wood can be produced in shorter periods of time as a result of increased growth rates of individual trees (Johnstone

1981b). The greatest relative gains of density management in lodgepole pine stands appear to occur on poorer sites, whereas the largest absolute gains occur on better sites (Johnstone 1983).

Recommended stocking densities for young lodgepole pine cited in the literature range widely depending on the desired end-product. Based on work in Alberta, Johnstone (1981a) recommends a stocking density of 2000-2500 stems per hectare to maximize yield per unit area. Johnstone (1981a) further recommends that young stands having less than 8000 stems per hectare should not be given high priority for treatment since losses to damaging agents can be expected to reduce this stocking level over time.

Diseased stems should be selected for removal during spacing operations. Damaging agents which may reduce stocking densities include root rot (*Armillaria mellea*), western gall rust (*Endocronartium harknessii*), terminal weevil (*Pissodes terminalis*), and small mammals such as porcupines, snowshoe hares, and red squirrels (Johnstone 1981a; Dermott 1985).

Cole (1975) concluded that though many studies involving the reduction of stand densities in lodgepole pine are reported in the literature, the formulation of specific recommendations based on their results is difficult. This difficulty arises as a result of inconsistencies in stand age, site; final stocking, parameters used to assess response (diameter, basal area, or volume, etc.), length of study, and the definition of growth (rate versus accumulation) (Cole 1975).

If overstocked conditions persist beyond the first 20 years of a stand's life, stagnation may become a problem, especially on poor sites (Dermott 1985). Mitchell and Goudie (1980) suggest that stagnant trees do not "stop" growing but that the time required to reach a merchantable size may double or triple. The biological causes of stagnation are largely unknown (Crane and Baker 1985). There are, however, many descriptive references to this phenomenon in the literature.

Based on research near Williams Lake, B.C., Bassman (1985) concluded that stagnation occurs at densities greater than 20 000-50 000 stems per hectare. He further found that stand basal area, stand and per tree biomass, and leaf area all began to decrease at 50 000 stems per hectare, and that both height growth and live crown ratios began to decline at 20 000 stems per hectare. Crane and Baker (1985) found that at 20 years of age annual height growth of lodgepole pine significantly decreased as stocking densities increased from 20 000-50 000 stems per hectare. They further found that there was a significant difference in height growth in 5000 stems per hectare stands compared to 20 000 stems per hectare stands, but that there was little difference in average height at these two stocking levels. They concluded that this height growth phenomenon might be symptomatic of the onset of stagnation in stands of similar density and age.

Crane and Baker (1985) found similar trends to those observed by Bassman (1985) in relation to leaf area and biomass. They also propose several theories as to the physiological causes of stagnation. The first of these is that lodgepole pine has a comparatively conservative physiology, allowing it to be tolerant of a wide variety of edaphic and climatic conditions. The second is that in spite of this wide tolerance, within a single growing season lodgepole pine growth is limited outside a narrow range of favourable environmental conditions. Condensing the favourable growing season to a short period may retard the growth of those individuals otherwise capable of exhibiting dominance. The combination of conservative physiology and reduced effective growing season leads to equal growth of both superior and inferior trees, resulting in the entire stand growing at a suppressed level. They suggest that the only remedy is to prevent young stands from becoming stagnant. This can be accomplished by reducing tree density before leaf area production reaches a maximum (i.e., before canopy closure) (Crane and Baker 1985). Crane and Baker (1985) recommend that densities in stands containing 100 000 stems per hectare should be reduced at a stand age of 5 years, 50 000 stems per hectare at 15 years, 20 000 stems per hectare at 18-20 years, and 5 000 stems per hectare before age 25 or 30.

Mitchell and Goudie (1980) have a different point of view. They suggest that height growth becomes repressed before trees become 2-3 m tall, whereas crown differentiation in repressed stands is similar to that found in normal stands even though the height growth of all trees is repressed. Based on research near Cranbrook, B.C., Mitchell and Goudie (1980) conclude that stands of 5000-50 000 stems per hectare should still be productive and that stagnation is likely beyond 50 000 stems per hectare. In contrast to Crane and Baker (1985), they further conclude that repressed trees do respond to release if stand densities are reduced at an early age. Mitchell and Goudie (1980) suggest that stands in which trees are not 2-3 m tall before the suppression of height growth, and where stocking exceeds 50 000 stems per hectare, should be classified as repressed. Using this definition of repression, they found that root

extension was not impeded by competing trees in repressed stands. Crown expansion, however, was. Trees growing at the edge of repressed stands exhibited normal growth, suggesting that light could be a limiting factor. This edge zone only extended 10-20 cm into the stand. They concluded that root development and the lack of regeneration in the 4-5 m immediately adjacent to the repressed stands indicated severe competition for moisture and that limited moisture may be a possible cause of repression. They further cite the hypothesis that the many small trees in dense stands have a much larger respiring surface area than under normal spacing. Consequently, a greater portion of the stand's energy is taken up in respiration rather than height growth. Mitchell and Goudie (1980) conclude that excessive respiration and limited moisture cause the onset of repression. They recommend hand spacing or strip thinning with leave strips of only two to three tree heights in width as the most appropriate techniques to maximize release. As an inexpensive alternative, they suggest burning and starting again. Similar stand treatment techniques have been recommended by other authors as well.

The Ministry of Forests (1984) describes the repression level as that density at which excessive competition causes dominant height growth to fall below the site potential. For survey purposes the repression level is presently defined as 10 000 stems per hectare (B. Ivanko, B.C. Ministry of Forests, Kamloops Region, pers. comm., Feb. 1987). This number of stems per hectare is somewhat arbitrary and, as was discussed at a meeting of foresters in the Cariboo Forest Region (1987), may require revision downward. Nevertheless, it is generally assumed that stands with greater than 10 000 stems per hectare do not reach merchantable size at rotation, assumed to be 70-90 years for interior lodgepole pine (Mitchell and Goudie 1980), which effectively removes these stands from the productive resource base (Forest Research Council of B.C. 1983).

Treatments are referred to as pre-commercial thinning or juvenile spacing when they are designed to reduce stocking densities in young stands and where the majority of cut trees are not merchantable; control stocking; prevent stagnation; and increase crop tree quality (Ministry of Forests 1984). In British Columbia this is accomplished through manual, chemical, mechanical, or a combination of techniques.

Manual spacing involves the use of hand tools such as clippers, shears and axes, and power tools such as brush cutters and chainsaws. The latter tools are generally costly (B.C. Ministry of Forests and Lands 1984; Johnstone 1985) and require both consistent supervision and trained workers (Herring 1981; B.C. Ministry of Forests 1984). Worker safety and skill are of particular concern in the case of power tool use. The B.C. Ministry of Forests considers the brush saw to be the most productive spacing tool under ideal conditions and the most effective where stems to be cut are less than 10 cm in diameter and where slope or debris do not impede worker movement. Manual spacing does, however, provide the greatest opportunity for controlling the future stand through appropriate selection of crop trees (Johnstone 1985).

Manual spacing is generally carried out in stands with 1000-25 000 stems per hectare, which are 10-30 years old and 2-10 m tall. Below 1000 stems per hectare the benefits of spacing would be minimal. At densities greater than 25 000 stems per hectare the cost of manual spacing becomes excessive (Johnstone 1985). Johnstone (1985) cites similar practices in Alberta where spacing is carried out at a stand age of 15 years, where trees are 2.5-3 m tall and densities greater than 7400 stems per hectare. By this time, dominance is presumably expressed, vigour and damage apparent and ingress complete.

Production rates in manual spacing operations of 0.1 ha/hr per person have been cited by Johnstone (1985). These rates decrease rapidly with increasing stand density.

"Hack and squirt" is the commonly used chemical spacing technique in British Columbia. This involves partially girdling the tree and injecting a systemic herbicide into the wound (B.C. Ministry of Forests 1984). This technique is generally used in stands with 10 000 or less stems per hectare, where average stem diameter exceeds 6 cm and the lower 1.5 m of the stems are branch free. According to the B.C. Ministry of Forests (1984), the major advantage of chemical spacing is that the treated trees remain standing, reducing the fire hazard and improving access over other spacing techniques which result in high slash accumulations. The major disadvantage cited is that the results of treatment are not immediately evident. Consequently, it becomes difficult to determine exactly which additional stems require treatment to achieve the best response and it does not provide crews with an immediate opportunity to view their accomplishments. Morale problems may also arise through individuals' unwillingness to use herbicides.

Mechanical spacing techniques have been developed to reduce stocking in stands so dense that manual spacing techniques are impractical (Cole 1975), and to improve treatment efficiencies in terms of both cost and area which can be treated within a given time (Johnstone 1985). This technique involves

clearing, mulching or crushing strips of trees, in rows alternating with those left standing, or in a checkerboard pattern (B.C. Ministry of Forests 1984). This is generally accomplished with a skidder with a front-mounted rotary cutting head or by a crawler tractor with a blade, or pulling a drum chopper.

Mechanical spacing is restricted by slope gradient (generally on slopes of less than 35% (Cole 1975)), roughness, soil texture, moisture, and obstructions such as boulders and stumps (B.C. Ministry of Forests 1984). This technique also has disadvantages related to crop tree response. After mechanical spacing, all trees in the leave strips or patches will form the next crop and only those trees on the edges of these strips will receive the full benefit of release. Edge trees in the reserve strips are often damaged and low branches in the cut strip may survive. Consequently, additional growth increment resulting from release will not necessarily be concentrated on the most desirable stems (B.C. Ministry of Forests 1984; Johnstone 1985).

Some of the problems associated with individual spacing techniques can be avoided through a combination of mechanical and manual spacing. The cost of this combination of treatments should be considerably lower than that incurred in manual spacing. Furthermore, manual spacing will be facilitated by ease of access through the mechanically spaced strips. Also, the combination of techniques allows specific trees to be selected for removal from the reserve strips, thereby providing an opportunity for sanitation (Herring 1981) and for concentrating increased growth on the most desirable stems.

Bella and Franceschi (1982) found that if reserve strips were not wider than 1.5 m, release effects occurred throughout the strip. However, they also concluded that even though 50% increases in diameter growth were observed 10-15 years after treatment, this was only half of the increase which could be expected through manual, selective density reduction techniques. Similar findings are cited by Johnstone (1982).

The review of available literature on stocking control in young lodgepole pine stands (less than 15 years of age) indicates a general lack of site-specific information on the effects of various spacing techniques and treatment intensities. Such information, though difficult to obtain as a result of the long-term commitment required to estimate response, is necessary before recommendations can be made about optimum management strategies (Johnstone 1985).

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## APPENDIX 2. A summary of the data used in FRDA 3.19

TABLE A2.1. A comparison of well-spaced and total stems per hectare (sph) with average duff thickness (mm) for selected sites in the MSd and SBSa subzones, in the Cariboo Forest Region.

| Subzone                               | Sample No. | Total sph | Well-spaced sph | Average duff thickness<br>mm (Range) |         |
|---------------------------------------|------------|-----------|-----------------|--------------------------------------|---------|
| MSd                                   | 1          | 4 845     | 1 221           | 29.2                                 | (0-99)  |
|                                       | 2          | 8 370     | 1 265           | 28.7                                 | (0-99)  |
|                                       | 3          | 11 086    | 1 471           | 21.8                                 | (0-50)  |
|                                       | 4          | 4 800     | 400             | 59.5                                 | (0-99)  |
|                                       | 5          | 4 071     | 999             | 57.9                                 | (5-99)  |
|                                       | 6          | 5 819     | 1 367           | 42.2                                 | (10-99) |
|                                       | 7          | 6 991     | 1 548           | 26.2                                 | (0-80)  |
|                                       | 8          | 1 956     | 664             | 28.3                                 | (10-80) |
|                                       | 9          | 3 084     | 923             | 41.4                                 | (0-90)  |
|                                       | 10         | 636       | 297             | 51.9                                 | (0-99)  |
|                                       | 11         | 1 117     | 532             | 29.9                                 | (0-99)  |
|                                       | 12         | 1 908     | 618             | 56.7                                 | (0-99)  |
|                                       | 13         | 14 957    | 1 338           | 32.7                                 | (0-99)  |
| Average duff thickness and total sph: |            |           |                 | and well-spaced sph:                 |         |
| $r = 0.678^a$                         |            |           |                 | $r = 0.800^b$                        |         |
| $r^2 = 46\%$                          |            |           |                 | $r^2 = 64\%$                         |         |
| SBSa                                  | 1          | 11 055    | 1 187           | 22.1                                 | (5-99)  |
|                                       | 2          | 1 000     | 225             | 38.9                                 | (0-99)  |
|                                       | 3          | 2 964     | 879             | 33.4                                 | (0-99)  |
|                                       | 4          | 8 993     | 1 100           | 19.1                                 | (0-99)  |
|                                       | 5          | 9 303     | 838             | 36.6                                 | (10-90) |
|                                       | 6          | 7 226     | 828             | 27.4                                 | (0-70)  |
|                                       | 7          | 2 978     | 1 094           | 43.2                                 | (5-99)  |
|                                       | 8          | 5 251     | 697             | 45.6                                 | (5-99)  |
|                                       | 9          | 1 792     | 806             | 32.1                                 | (0-70)  |
|                                       | 10         | 6 320     | 1 600           | 29.2                                 | (0-99)  |
| Average duff thickness and total sph: |            |           |                 | and well-spaced sph:                 |         |
| $r = 0.768^b$                         |            |           |                 | $r = 0.872$                          |         |
| $r^2 = 59\%$                          |            |           |                 | $r^2 = 76\%$                         |         |

a Significant at 0.05.

b Significant at 0.01.

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin

| Subzone | Sample # | Stocking status (ha) |     | Stems per hectare |       | Treatment | Aspect | Site characteristics |           |            |   |
|---------|----------|----------------------|-----|-------------------|-------|-----------|--------|----------------------|-----------|------------|---|
|         |          | NSR                  | SR  | Well-spaced       | Total |           |        | Slope                | Elev. (m) | Site class |   |
| MSd     | 1        | 22                   | 108 | 461               | 2313  | 1094      | 8926   | N                    | 15        | 1400       | M |
|         | 2        | 0                    | 28  | 0                 | 0     | 960       | 6248   | NW                   | 30        | 1370       | M |
|         | 3        | 74                   | 27  | 551               | 1957  | 987       | 4673   | NW                   | 25        | 1370       | M |
|         | 4        | 0                    | 59  | 0                 | 0     | 1340      | 11,596 | E                    | 25        | 1370       | P |
|         | 5        | 33                   | 46  | 283               | 1078  | 1090      | 7342   | SW                   | 0         | 1250       | P |
|         | 6        | 10                   | 44  | 433               | 4671  | 1434      | 10,387 | NW                   | 20        | 1280       | M |
|         | 7        | 8                    | 29  | 167               | 200   | 903       | 2823   | NW                   | 20        | 1280       | M |
|         | 8        | 0                    | 6   | 0                 | 0     | 711       | 2333   | W                    | 20        | 1220       | M |
|         | 9        | 34                   | 22  | 494               | 1854  | 1300      | 7445   | SW                   | 5         | 1220       | P |
|         | 10       | 0                    | 36  | 0                 | 0     | 1278      | 8567   | NW                   | 30        | 1370       | M |
|         | 11       | 74                   | 0   | 202               | 579   | 0         | 0      | S                    | 15        | 1370       | M |
|         | 12       | 30                   | 49  | 446               | 1877  | 1053      | 9223   | S                    | 15        | 1370       | M |
|         | 13       | 81                   | 0   | 0                 | 0     | 561       | 1274   | S                    | 15        | 1370       | M |
|         | 14       | 73                   | 0   | 614               | 2203  | 0         | 0      | N                    | 0         | 1280       | M |
|         | 15       | 0                    | 76  | 0                 | 0     | 771       | 4118   | NE                   | 10        | 1220       | M |
|         | 16       | 90                   | 31  | 325               | 561   | 931       | 3777   | N                    | 40        | 1220       | M |
|         | 17       | 0                    | 8   | 0                 | 0     | 1000      | 2900   | SW                   | 0         | 1200       | P |
| SBSa    | 1        | 0                    | 45  | 0                 | 0     | 1588      | 1600   | N                    | 5         | 1400       | P |
|         | 2        | 0                    | 24  | 0                 | 0     | 1187      | 11055  | NE                   | 10        | 1300       | P |
|         | 3        | 0                    | 57  | 0                 | 0     | 846       | 3323   | NE                   | 10        | 1300       | P |
|         | 4        | 27                   | 0   | 723               | 2174  | 0         | 0      | NE                   | 10        | 914        | M |
|         | 5        | 62                   | 0   | 1000              | 2270  | 0         | 0      | NE                   | 10        | 914        | M |
|         | 6        | 0                    | 68  | 0                 | 0     | 860       | 2120   | N                    | 15        | 1067       | P |
|         | 7        | 0                    | 74  | 0                 | 0     | 707       | 1700   | NE                   | 10        | 1300       | P |
|         | 8        | 41                   | 78  | 539               | 1783  | 1215      | 10194  | E                    | 5         | 1219       | M |
|         | 9        | 0                    | 3   | 0                 | 0     | 1000      | 5000   | E                    | 5         | 1219       | M |

TABLE A2.2. (continued)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Stems per hectare |       | Treatment | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|-----|-------------|-------|-------------------|-------|-----------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced       | SR    |           |        | Slope                | Elev. (m) | Site class |
| SBSa    | 10       | 10                   | 0   | 267         | 833   | 0                 | 0     | —         | F      | 0                    | 1280      | P          |
|         |          | 3                    |     | 640         | 1360  |                   |       | —         |        |                      |           |            |
|         | 11       | 36                   | 37  | 394         | 1525  | 697               | 5251  | MTRAILP   | S      | 10                   | 1372      | P          |
|         | 12       | 0                    | 60  | 0           | 0     | 1600              | 1600  | —         | F      | 0                    | 1210      | P          |
|         | 13       | 0                    | 8   | 0           | 0     | 1504              | 8311  | —         | W      | 10                   | 1371      | P          |
|         |          | 17                   |     |             |       | 1014              | 2109  | —         |        |                      |           |            |
|         |          | 18                   |     |             |       | 944               | 3305  | —         |        |                      |           |            |
|         | 14       | 0                    | 137 | 0           | 0     | 1161              | 7517  | —         | S      | 10                   | 1128      | P          |
|         | 15       | 32                   | 75  | 76          | 162   | 929               | 2833  | MTRAILP   | SE     | 10                   | 1524      | M          |
|         | 16       | 84                   | 100 | 678         | 3346  | 1125              | 4602  | —         | NE     | 5                    | 1200      | M          |
|         | 17       | 5                    | 67  | 407         | 1057  | 965               | 7471  | MTRAILP   | SW     | 10                   | 1524      | P          |
|         | 18       | 10                   | 45  | 263         | 600   | 446               | 5277  | —         | W      | 20                   | 1371      | P          |
|         | 19       | 0                    | 33  | 0           | 0     | 838               | 9303  | —         | SW     | 15                   | 1371      | P          |
|         | 20       | 0                    | 87  | 0           | 0     | 828               | 7226  | —         | SW     | 15                   | 1371      | P          |
|         | 21       | 0                    | 29  | 0           | 0     | 1060              | 3340  | —         |        | 5                    | 1524      | P          |
|         | 22       | 60                   | 0   | 710         | 1959  | 0                 | 0     | —         | N      | 10                   | 1371      | P          |
|         | 23       | 0                    | 25  | 0           | 0     | 973               | 3240  | —         | F      | 0                    | 1200      | P          |
|         | 24       | 0                    | 22  | 0           | 0     | 1064              | 3527  | —         | F      | 0                    | 1200      | P          |
|         | 25       | 0                    | 35  | 0           | 0     | 1368              | 10336 | —         | F      | 0                    | 1100      | P          |
|         | 26       | 0                    | 33  | 0           | 0     | 969               | 3600  | —         | N      | 10                   | 1524      | P          |
|         | 27       | 12                   | 37  | 284         | 589   | 1063              | 4032  | MTRAILP   | SW     | 10                   | 1524      | P          |
|         | 28       | 0                    | 113 | 0           | 0     | 1300              | 4125  | —         | S      | 10                   | 1524      | P          |
|         | 29       | 0                    | 36  | 0           | 0     | 1471              | 11086 | —         | W      | 10                   | 1618      | P          |
|         | 30       | 0                    | 46  | 0           | 0     | 1265              | 8370  | —         | N      | 10                   | 1618      | P          |
|         | 31       | 0                    | 66  | 0           | 0     | 1225              | 4845  | —         | W      | 15                   | 1618      | P          |
|         | 32       | 0                    | 69  | 0           | 0     | 1048              | 4870  | —         | SW     | 15                   | 1524      | P          |

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin (continued)

| Subzone | Sample # | Stocking status (ha) |      | NSR         |       | Stems per hectare |       | Treatment     | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|------|-------------|-------|-------------------|-------|---------------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR   | Well-spaced | Total | Well-spaced       | Total |               |        | Slope                | Elev. (m) | Site class |
| SBSa    | 33       | 0                    | 59   | 0           | 0     | 1166              | 3559  | —             | S      | 10                   | 1524      | P          |
|         | 34       | 0                    | 67   | 0           | 0     | 1116              | 3981  | GROAD         | S      | 10                   | 1524      | P          |
|         | 35       | 0                    | 37   | 0           | 0     | 1379              | 4903  | —             | S      | 5                    | 1524      | P          |
|         | 36       | 0                    | 60   | 0           | 0     | 1654              | 8231  | MCHAIN        | S      | 10                   | 1524      | P          |
|         | 37       | 0                    | 52   | 0           | 0     | 1367              | 5819  | —             | E      | 5                    | 1524      | P          |
|         | 38       | 0                    | 12   | 0           | 0     | 1317              | 3825  | —             | NE     | 10                   | 1524      | P          |
|         |          | 14                   |      |             |       | 1167              | 5313  |               |        |                      |           |            |
|         | 39       | 27                   | 24   | 439         | 1236  | 1148              | 4091  | MTRAILP       | N      | 15                   | 1524      | P          |
|         | 40       | 10                   | 1396 | 0           | 0     | 1200              | 6000  | MMACHN,       | V      | 5                    | 1370      | P          |
|         | 41       | 0                    | 5    | 0           | 0     | 1875              | 1975  | —             | S      | 5                    | 1019      | P          |
|         | 42       | 56                   | 44   | 338         | 1138  | 879               | 2965  | —             | W      | 5                    | 1219      | P          |
|         | 43       | 0                    | 31   | 0           | 0     | 1142              | 6321  | —             | F      | 0                    | 1070      | M          |
|         | 44       | 22                   | 0    | 568         | 1288  | 0                 | 0     | —             | F      | 0                    | 1035      | M          |
|         | 45       | 0                    | 48   | 0           | 0     | 967               | 2507  | MCHAINN       | SE     | 20                   | 1010      | M          |
|         | 46       | 80                   | 0    | 175         | 884   | 0                 | 0     | MCHAINH       | SE     | 20                   | 1010      | M          |
|         | 47       | 47                   | 21   | 223         | 1042  | 1000              | 3338  | MCHAINN       | S      | 20                   | 1190      | M          |
|         | 48       | 0                    | 82   | 0           | 0     | 1371              | 8307  | MCHAINN       | S      | 20                   | 1130      | M          |
|         | 49       | 0                    | 31   | 0           | 0     | 992               | 1400  | BBROADH       | S      | 25                   | 1140      | M          |
|         | 50       | 76                   | 0    | 114         | 289   | 0                 | 0     | MCHAINN       | S      | 5                    | 1140      | M          |
|         | 51       | 0                    | 42   | 0           | 0     | 629               | 1757  | BPILEN        | F      | 0                    | 1061      | M          |
|         | 52       | 0                    | 57   | 0           | 0     | 676               | 3208  | —             | SW     | 5                    | 1220      | M          |
|         | 53       | 0                    | 81   | 0           | 0     | 1178              | 3704  | —             | N      | 20                   | 1100      | P          |
|         | 54       | 0                    | 44   | 0           | 0     | 783               | 2443  | —             | SE     | 15                   | 1070      | M          |
|         | 55       | 0                    | 129  | 0           | 0     | 1191              | 5047  | MPILE, BSPOTH | N      | 20                   | 1280      | M          |
|         | 56       | 0                    | 83   | 0           | 0     | 928               | 3544  | MPILE, BSPOTH | N      | 20                   | 1080      | M          |
|         | 57       | 0                    | 84   | 0           | 0     | 1045              | 4042  | —             | SE     | 0                    | 980       | M          |

TABLE A2.2. (continued)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Stems per hectare |       | Treatment      | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|-----|-------------|-------|-------------------|-------|----------------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced       | Total |                |        | Slope                | Elev. (m) | Site class |
| SBSa    | 58       | 0                    | 101 | 0           | 0     | 1028              | 3800  | MCHAINN        | W      | 20                   | 1220      | M          |
|         | 59       | 0                    | 55  | 0           | 0     | 1148              | 5685  | —              | F      | 0                    | 1070      | M          |
|         | 60       | 0                    | 59  | 0           | 0     | 1063              | 7249  | MCHAINN        | S      | 10                   | 1220      | M          |
|         | 61       | 22                   | 34  | 525         | 1363  | 958               | 3221  | MCHAINN        | S      | 10                   | 1220      | M          |
|         | 62       | 0                    | 63  | 0           | 0     | 1244              | 8778  | —              | S      | 15                   | 1220      | M          |
|         | 63       | 0                    | 74  | 0           | 0     | 960               | 2360  | MCHAINN        | V      | 10                   | 1370      | M          |
|         | 64       | 0                    | 62  | 0           | 0     | 766               | 1840  | MCHAINN        | V      | 10                   | 1350      | M          |
|         | 65       | 0                    | 77  | 0           | 0     | 860               | 1720  | MCHAINN        | W      | 5                    | 1300      | P          |
|         | 66       | 0                    | 32  | 0           | 0     | 714               | 2067  | —              | S      | 5                    | 1310      | M          |
|         | 67       | 0                    | 31  | 0           | 0     | 1009              | 2200  | —              | S      | 10                   | 1370      | M          |
|         | 68       | 38                   | 0   | 527         | 1395  | 0                 | 0     | BWILDA         | W      | 5                    | 1370      | M          |
|         | 69       | 0                    | 117 | 0           | 0     | 818               | 2850  | BWILDA         | E      | 15                   | 1400      | M          |
|         | 70       | 0                    | 37  | 0           | 0     | 900               | 4544  | MCHAINN, BWILD | SW     | 10                   | 1370      | M          |
|         | 71       | 0                    | 63  | 0           | 0     | 1092              | 2980  | MCHAINN        | SW     | 15                   | 1340      | M          |
|         | 72       | 0                    | 85  | 0           | 0     | 1289              | 10880 | —              | SW     | 20                   | 1340      | M          |
|         | 73       | 0                    | 65  | 0           | 0     | 650               | 1962  | BBROADH, BWILD | V      | 25                   | 1275      | M          |
|         | 74       | 0                    | 113 | 0           | 0     | 560               | 1285  | BBROADH, BWILD | V      | 25                   | 1370      | M          |
|         | 75       | 0                    | 35  | 0           | 0     | 693               | 1378  | BBROADH, BWILD | V      | 25                   | 1190      | M          |
|         | 76       | 28                   | 42  | 426         | 2787  | 869               | 2831  | MMACHH         | S      | 10                   | 1070      | M          |
|         | 77       | 0                    | 54  | 0           | 0     | 1006              | 3971  | MCHAINH        | W      | 10                   | 1010      | M          |
|         | 78       | 0                    | 64  | 0           | 0     | 1006              | 3971  | MCHAINH        | W      | 10                   | 1010      | M          |
|         | 79       | 46                   | 0   | 692         | 1810  | 0                 | 0     | MMACHH         | S      | 10                   | 1100      | M          |
|         | 80       | 26                   | 8   | 337         | 621   | 1225              | 3825  | MTRAILP        | S      | 10                   | 1160      | M          |
|         | 81       | 86                   | 0   | 574         | 1077  | 0                 | 0     | MCHAINN, BWILD | W      | 15                   | 1280      | M          |
|         | 82       | 0                    | 25  | 0           | 0     | 1064              | 4609  | MCHAINN, MHAND | W      | 10                   | 1100      | M          |
|         | 83       | 0                    | 11  | 0           | 0     | 1273              | 3000  | MCHAINN        | E      | 55                   | 1070      | M          |

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin (continued)

| Subzone | Sample # | Stocking status (ha) |     | Stems per hectare |       |             | Treatment | Aspect                   | Site characteristics |       |           |            |
|---------|----------|----------------------|-----|-------------------|-------|-------------|-----------|--------------------------|----------------------|-------|-----------|------------|
|         |          | NSR                  | SR  | Well-spaced       | Total | Well-spaced |           |                          | SR                   | Slope | Elev. (m) | Site class |
| SBSa    | 84       | 0                    | 57  | 0                 | 0     | 1127        | 7773      | BWINDRH, MCHAINN, BPILEH | V                    | 10    | 1220      | M          |
|         | 85       | 0                    | 75  | 0                 | 0     | 1095        | 5200      | MCHAINN                  | W                    | 25    | 1220      | M          |
|         | 86       | 0                    | 38  | 0                 | 0     | 905         | 3068      | MWINDRH, BWINDR          | NE                   | 20    | 1220      | M          |
|         | 87       | 0                    | 132 | 0                 | 0     | 1152        | 5515      | MCHAINN                  | SW                   | 25    | 1220      | M          |
|         | 88       | 0                    | 19  | 0                 | 0     | 989         | 2800      | MCHAINN                  | W                    | 10    | 1100      | M          |
|         | 89       | 0                    | 73  | 0                 | 0     | 1364        | 9653      | —                        | NE                   | 20    | 1220      | M          |
|         | 90       | 0                    | 55  | 0                 | 0     | 1354        | 4712      | WCHAINN                  | V                    | 5     | 980       | M          |
|         | 91       | 0                    | 21  | 0                 | 0     | 1034        | 4097      | —                        | NW                   | 0     | 910       | M          |
|         | 92       | 0                    | 33  | 0                 | 0     | 4416        | 4438      | —                        | S                    | 10    | 910       | M          |
|         | 93       | 0                    | 30  | 0                 | 0     | 1420        | 6840      | BSPOTN                   | NE                   | 20    | 1220      | M          |
|         | 94       | 0                    | 54  | 0                 | 0     | 1030        | 6840      | BSPOTN                   | NE                   | 20    | 1220      | M          |
|         | 95       | 0                    | 43  | 0                 | 0     | 1170        | 6469      | BSPOTN                   | NE                   | 20    | 1220      | M          |
|         |          |                      |     | 25                |       | 1044        | 4785      |                          |                      |       |           |            |
|         | 96       | 13                   | 20  | 141               | 447   | 980         | 5050      | BWINDR, BSPOT            | N                    | 20    | 1372      | M          |
|         | 97       | 128                  | 0   | 513               | 2836  | 0           | 0         | MWINDR, BSPOT, BPILEN    | 0                    | 0     | 1220      | M          |
|         | 98       | 67                   | 0   | 693               | 3030  | 0           | 0         | BWINDR, BSPOT            | N                    | 20    | 1372      | M          |
|         | 99       | 19                   | 53  | 445               | 2073  | 965         | 5158      | MCHAINH                  | N                    | 20    | 1150      | M          |
|         | 100      | 0                    | 13  | 0                 | 0     | 778         | 3378      | —                        | NW                   | 20    | 1280      | M          |
|         | 101      | 0                    | 49  | 0                 | 0     | 1305        | 6732      | BSPOT, MCHAIN            | W                    | 25    | 1220      | M          |
|         | 102      | 0                    | 67  | 0                 | 0     | 878         | 3404      | BBROAD, MCHAIN           | W                    | 25    | 1220      | M          |
|         |          |                      |     | 7                 |       | 1444        | 8189      |                          |                      |       |           |            |
|         | 103      | 0                    | 40  | 0                 | 0     | 1000        | 5506      | BSPOT, MCHAIN            | W                    | 25    | 1220      | M          |
|         | 104      | 34                   | 66  | 518               | 2318  | 955         | 5866      | MCHAIN, BWINDR           | NW                   | 20    | 1400      | M          |
|         | 105      | 0                    | 81  | 0                 | 0     | 1338        | 14,957    | MWINDR, BWINDR, MCHAIN   | NW                   | 40    | 1400      | P          |
|         | 106      | 0                    | 45  | 0                 | 0     | 920         | 10867     | BWINDR, MCHAIN           | NW                   | 40    | 1400      | M          |
|         | 107      | 0                    | 70  | 0                 | 0     | 625         | 2300      | BPILE                    | W                    | 30    | 1370      | M          |

TABLE A2.2. (continued)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Stems per hectare |       | Treatment     | Aspect           | Site characteristics |           |            |   |
|---------|----------|----------------------|-----|-------------|-------|-------------------|-------|---------------|------------------|----------------------|-----------|------------|---|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced       | Total |               |                  | Slope                | Elev. (m) | Site class |   |
| SBSa    | 108      | 0                    | 82  | 0           | 0     | 0                 | 1350  | 2446          | —                | V                    | 15        | 1280       | M |
|         | 109      | 0                    | 5   | 0           | 0     | 0                 | 288   | 400           | —                | V                    | 15        | 1370       | P |
|         | 110      | 41                   | 0   | 556         | 1280  | 0                 | 0     | 0             | —                | V                    | 15        | 1280       | M |
|         | 111      | 0                    | 99  | 0           | 0     | 0                 | 1874  | 6167          | —                | V                    | 15        | 1280       | M |
|         | 112      | 0                    | 51  | 0           | 0     | 0                 | 1107  | 7696          | —                | N                    | 10        | 1220       | M |
|         | 113      | 0                    | 37  | 0           | 0     | 0                 | 1422  | 7119          | BWINDR           | NW                   | 40        | 1220       | M |
|         | 114      | 0                    | 2   | 0           | 0     | 0                 | 800   | 4333          | —                | NW                   | 5         | 1070       | G |
|         | 115      | 37                   | 0   | 259         | 555   | 0                 | 0     | 0             | MCHAINN          | SE                   | 20        | 1220       | M |
|         | 116      | 0                    | 45  | 0           | 0     | 0                 | 864   | 1616          | MCHAINN, MPOST   | SE                   | 15        | 1370       | M |
|         | 117      | 13                   | 25  | 369         | 1969  | 1165              | 5513  | 0             | —                | SW                   | 5         | 1220       | M |
|         | 118      | 56                   | 15  | 316         | 479   | 1200              | 3267  | 0             | MCHAINN          | NE                   | 15        | 1310       | M |
|         | 119      | 0                    | 104 | 0           | 0     | 1181              | 5477  | 0             | MCHAIN, BPILE    | SW                   | 30        | 1400       | M |
|         | 120      | 44                   | 0   | 262         | 450   | 0                 | 0     | 0             | MCHAIN, BPILE    | S                    | 5         | 1190       | M |
|         | 121      | 88                   | 0   | 86          | 185   | 0                 | 0     | 0             | BPILE            | SW                   | 20        | 1250       | M |
|         | 122      | 82                   | 0   | 532         | 1117  | 0                 | 0     | 0             | —                | NW                   | 40        | 1219       | M |
|         | 123      | 94                   | 0   | 418         | 1366  | 0                 | 0     | 0             | —                | F                    | 0         | 1219       | P |
|         | 124      | 77                   | 0   | 318         | 631   | 0                 | 0     | 0             | —                | E                    | 5         | 1250       | M |
|         | 125      | 98                   | 0   | 260         | 2218  | 0                 | 0     | 0             | MCHAINN, MTRAILP | NE                   | 10        | 975        | G |
|         | 126      | 0                    | 57  | 0           | 0     | 845               | 2718  | 0             | —                | W                    | 25        | 1310       | M |
|         | 127      | 47                   | 0   | 317         | 600   | 0                 | 0     | 0             | —                | SW                   | 10        | 1250       | M |
|         | 128      | 0                    | 9   | 0           | 0     | 800               | 2150  | 0             | —                | SE                   | 2         | 1280       | G |
| 129     | 97       | 0                    | 466 | 2066        | 0     | 0                 | 0     | MCHAIN, BSPOT | NE               | 5                    | 1038      | M          |   |
| 130     | 36       | 28                   | 223 | 642         | 700   | 700               | 0     | BSPOTH        | N                | 20                   | 1130      | P          |   |
| 131     | 0        | 72                   | 0   | 0           | 723   | 2309              | 0     | —             | SW               | 25                   | 1000      | M          |   |
| 132     | 34       | 0                    | 694 | 1743        | 0     | 0                 | 0     | MWINDR, BSPOT | N                | 12                   | 1050      | M          |   |
| 133     | 45       | 0                    | 70  | 131         | 0     | 0                 | 0     | BPILE         | F                | 0                    | 1220      | M          |   |

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin (continued)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Well-spaced |       | Siems per hectare |                        | Treatment              | Aspect | Site characteristics |           |
|---------|----------|----------------------|-----|-------------|-------|-------------|-------|-------------------|------------------------|------------------------|--------|----------------------|-----------|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced | Total | Well-spaced       | Total                  |                        |        | Slope                | Elev. (m) |
| SBSa    | 134      | 0                    | 95  | 0           | 0     | 0           | 1280  | 5290              | —                      | —                      | W      | 10                   | 1100      |
|         | 135      | 0                    | 7   | 0           | 0     | 0           | 400   | 1350              | —                      | —                      | F      | 0                    | 1030      |
|         | 136      | 0                    | 89  | 0           | 0     | 0           | 861   | 9580              | —                      | —                      | SW     | 10                   | 1619      |
|         | 137      | 0                    | 113 | 0           | 0     | 0           | 949   | 3949              | BBROAD                 | BBROAD                 | S      | 5                    | 1280      |
|         | 138      | 0                    | 13  | 0           | 0     | 0           | 1516  | 7726              | MPILE                  | MPILE                  | SE     | 10                   | 1220      |
|         | 139      | 0                    | 48  | 0           | 0     | 0           | 854   | 3434              | —                      | —                      | W      | 15                   | 1150      |
|         | 140      | 64                   | 0   | 538         | 2518  | 0           | 0     | 0                 | BBROAD, MMACH, G BLOCK | BBROAD, MMACH, G BLOCK | E      | 5                    | 1050      |
|         | 141      | 0                    | 96  | 0           | 0     | 0           | 1289  | 5333              | —                      | —                      | SW     | 15                   | 1341      |
|         | 142      | 0                    | 86  | 0           | 0     | 0           | 747   | 2635              | MCHAIN, GROAD          | MCHAIN, GROAD          | F      | 0                    | 1280      |
|         | 143      | 0                    | 60  | 0           | 0     | 0           | 806   | 1792              | —                      | —                      | SW     | 15                   | 1280      |
|         | 144      | 0                    | 53  | 0           | 0     | 0           | 1179  | 4500              | —                      | —                      | W      | 15                   | 1280      |
|         | 145      | 0                    | 46  | 0           | 0     | 0           | 854   | 4955              | —                      | —                      | SW     | 10                   | 1311      |
|         | 146      | 0                    | 29  | 0           | 0     | 0           | 1050  | 5350              | MCHAIN, GROAD          | MCHAIN, GROAD          | S      | 15                   | 1250      |
|         | 147      | 0                    | 75  | 0           | 0     | 0           | 1050  | 5350              | MCHAIN, GROAD          | MCHAIN, GROAD          | S      | 15                   | 1250      |
|         | 148      | 0                    | 68  | 0           | 0     | 0           | 1279  | 1279              | BBROAD                 | BBROAD                 | N      | 5                    | 1275      |
| SBSb    | 149      | 0                    | 11  | 0           | 0     | 0           | 920   | 1780              | —                      | —                      | N      | 10                   | 1010      |
|         | 150      | 0                    | 123 | 0           | 0     | 0           | 559   | 4024              | G BLOCK                | G BLOCK                | S      | 10                   | 1150      |
|         | 151      | 0                    | 12  | 0           | 0     | 0           | 1440  | 6555              | —                      | —                      | F      | 0                    | 1200      |
|         | 152      | 0                    | 37  | 0           | 0     | 0           | 1600  | 9750              | BWIND                  | BWIND                  | F      | 0                    | 1200      |
|         | 1        | 0                    | 67  | 0           | 0     | 0           | 1041  | 4000              | MCHAIN                 | MCHAIN                 | E      | 20                   | 910       |
|         | 2        | 3                    | 0   | 650         | 1000  | 0           | 0     | 0                 | —                      | —                      | F      | 5                    | 790       |
|         | 3        | 0                    | 43  | 0           | 0     | 0           | 940   | 3475              | MCHAIN                 | MCHAIN                 | E      | 20                   | 915       |
|         | 4        | 7                    | 28  | 200         | 429   | 1121        | 5086  | 5086              | MCHAIN                 | MCHAIN                 | F      | 0                    | 1067      |
|         | 5        | 0                    | 24  | 0           | 0     | 1035        | 2887  | 2887              | MCHAIN, MHAND          | MCHAIN, MHAND          | S      | 10                   | 1067      |
|         | 6        | 0                    | 28  | 0           | 0     | 814         | 2236  | 2236              | MHAND                  | MHAND                  | F      | 0                    | 950       |
|         | 7        | 0                    | 66  | 0           | 0     | 796         | 2356  | 2356              | MHAND                  | MHAND                  | F      | 0                    | 1040      |

TABLE A2.2. (continued)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Stems per hectare |       | SR          |       | Treatment     | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|-----|-------------|-------|-------------------|-------|-------------|-------|---------------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced       | Total | Well-spaced | Total |               |        | Slope                | Elev. (m) | Site class |
| SBSb    | 8        | 0                    | 53  | 0           | 0     | 0                 | 753   | 1447        |       | MHAND         | F      | 0                    | 950       | M          |
|         | 9        | 0                    | 45  | 0           | 0     | 0                 | 1289  | 10,575      |       | MCHAIN        | V      | 20                   | 1160      | M          |
|         | 10       | 0                    | 68  | 0           | 0     | 0                 | 1103  | 5764        |       | MCHAIN        | V      | 20                   | 1280      | M          |
|         | 11       | 0                    | 75  | 0           | 0     | 0                 | 1168  | 5176        |       | MCHAIN        | V      | 20                   | 1310      | M          |
|         | 12       | 0                    | 49  | 0           | 0     | 0                 | 951   | 7506        |       | MCHAIN        | NE     | 20                   | 1340      | M          |
|         | 13       | 0                    | 81  | 0           | 0     | 0                 | 1234  | 5926        |       | MCHAIN        | E      | 20                   | 1340      | M          |
|         | 14       | 0                    | 49  | 0           | 0     | 0                 | 1193  | 7723        |       | —             | V      | 0                    | 1220      | M          |
|         | 15       | 0                    | 35  | 0           | 0     | 0                 | 1021  | 2842        |       | MCHAIN, BSPOT | NW     | 10                   | 1067      | M          |
|         | 16       | 0                    | 111 | 0           | 0     | 0                 | 790   | 1687        |       | —             | NE     | 5                    | 1067      | M          |
|         | 17       | 0                    | 73  | 0           | 0     | 0                 | 927   | 2033        |       | MPILE         | E      | 10                   | 1129      | M          |
|         | 18       | 0                    | 74  | 0           | 0     | 0                 | 1109  | 3727        |       | BBROAD        | E      | 20                   | 1190      | M          |
|         | 19       | 0                    | 23  | 0           | 0     | 0                 | 843   | 2085        |       | —             | NE     | 40                   | 1010      | M          |
|         | 21       | 0                    | 5   | 0           | 0     | 0                 | 1450  | 46.50       |       | MHAND         | F      | 0                    | 950       | M          |
|         | 22       | 97                   | 0   | 664         | 1956  | 0                 | 0     | 0           | 0     | —             | W      | 10                   | 1300      | M          |
|         | 23       | 0                    | 61  | 0           | 0     | 0                 | 923   | 3084        |       | —             | W      | 10                   | 1300      | M          |
|         | 24       | 0                    | 44  | 0           | 0     | 0                 | 895   | 2800        |       | —             | S      | 10                   | 1040      | M          |
|         | 25       | 0                    | 60  | 0           | 0     | 0                 | 659   | 2792        |       | MMACH         | E      | 5                    | 1100      | M          |
|         | 26       | 90                   | 0   | 666         | 2955  | 0                 | 0     | 0           | 0     | MMACH, GROADS | N      | 20                   | 1130      | M          |
|         | 27       | 0                    | 59  | 0           | 0     | 0                 | 967   | 1500        |       | —             | S      | 10                   | 830       | M          |
|         | 28       | 0                    | 70  | 0           | 0     | 0                 | 1156  | 4744        |       | MCHAIN        | E      | 10                   | 980       | M          |
|         | 29       | 0                    | 56  | 0           | 0     | 0                 | 1103  | 4376        |       | MCHAIN        | V      | 5                    | 1070      | M          |
|         | 30       | 0                    | 56  | 0           | 0     | 0                 | 1100  | 2278        |       | MCHAIN        | V      | 15                   | 1070      | M          |
|         | 31       | 0                    | 87  | 0           | 0     | 0                 | 954   | 3359        |       | MCHAIN        | W      | 10                   | 1070      | M          |
|         | 32       | 0                    | 128 | 0           | 0     | 0                 | 1100  | 3913        |       | MCHAIN        | V      | 10                   | 1070      | M          |
|         | 33       | 0                    | 64  | 0           | 0     | 0                 | 1210  | 6617        |       | MCHAIN        | F      | 5                    | 1070      | M          |
|         | 34       | 0                    | 75  | 0           | 0     | 0                 | 851   | 3154        |       | BSPOT, MCHAIN | SE     | 10                   | 1220      | M          |

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin (continued)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Stems per hectare |       | Treatment            | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|-----|-------------|-------|-------------------|-------|----------------------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced       | Total |                      |        | Slope                | Elev. (m) | Site class |
| SBSb    | 34       | 0                    | 75  | 0           | 0     | 851               | 3154  | BSPOT, MCHAIN        | SE     | 10                   | 1220      | M          |
|         | 35       | 0                    | 50  | 0           | 0     | 967               | 4367  | MCHAIN, BSPOT        | F      | 2                    | 980       | G          |
|         | 36       | 0                    | 117 | 0           | 0     | 4413              | 4680  | MCHAIN               | S      | 5                    | 1040      | G          |
|         | 37       | 0                    | 46  | 0           | 0     | 2066              | 2133  | MCHAIN               | S      | 50                   | 1040      | G          |
|         | 38       | 0                    | 85  | 0           | 0     | 1464              | 6957  | MCHAIN               | V      | 5                    | 1130      | M          |
|         | 39       | 0                    | 26  | 0           | 0     | 720               | 3370  | MCHAIN               | E      | 10                   | 1070      | G          |
|         | 40       | 0                    | 9   | 0           | 0     | 627               | 2780  | —                    | NW     | 10                   | 1190      | M          |
|         | 41       | 43                   | 0   | 446         | 2079  | 0                 | 0     | —                    | SW     | 10                   | 1220      | P          |
|         | 42       | 0                    | 117 | 0           | 0     | 883               | 2433  | MCHAIN               | N      | 10                   | 1070      | M          |
|         | 43       | 0                    | 28  | 0           | 0     | 1064              | 3007  | MCHAIN               | NW     | 10                   | 1040      | M          |
|         | 44       | 0                    | 58  | 0           | 0     | 1047              | 3480  | MCHAIN               | N      | 10                   | 1010      | M          |
|         | 45       | 0                    | 78  | 0           | 0     | 1295              | 4420  | MCHAIN               | NW     | 10                   | 1070      | M          |
|         | 46       | 0                    | 29  | 0           | 0     | 917               | 6823  | BWIND, MCHAIN        | F      | 0                    | 1310      | M          |
|         | 47       | 0                    | 148 | 0           | 0     | 1148              | 5607  | —                    | N      | 10                   | 1190      | M          |
|         | 48       | 0                    | 79  | 0           | 0     | 1229              | 8246  | —                    | V      | 10                   | 1220      | M          |
|         | 49       | 0                    | 45  | 0           | 0     | 1600              | 1600  | GROAD                | S      | 20                   | 1098      | M          |
|         | 50       | 0                    | 49  | 0           | 0     | 1009              | 2843  | —                    | S      | 15                   | 830       | M          |
|         | 51       | 0                    | 82  | 0           | 0     | 940               | 4400  | —                    | N      | 0                    | 1235      | M          |
|         | 52       | 0                    | 8   | 0           | 0     | 943               | 3000  | —                    | S      | 10                   | 915       | G          |
|         | 53       | 21                   | 48  | 200         | 463   | 1132              | 4782  | —                    | NW     | 60                   | 1219      | P          |
|         | 54       | 87                   | 0   | 374         | 1096  | 0                 | 0     | MCHAIN               | S      | 10                   | 1220      | M          |
|         | 55       | 0                    | 58  | 0           | 0     | 786               | 1768  | —                    | SW     | 10                   | 910       | M          |
|         | 56       | 28                   | 0   | 486         | 1964  | 0                 | 0     | MCHAIN               | W      | 10                   | 1220      | M          |
|         | 57       | 0                    | 37  | 0           | 0     | 1050              | 4811  | —                    | N      | 0                    | 975       | M          |
|         | 58       | 0                    | 71  | 0           | 0     | 1162              | 5472  | —                    | N      | 10                   | 975       | G          |
|         | 59       | 32                   | 0   | 145         | 207   | 0                 | 0     | MPILE, BSPOT, MCHAIN | E      | 10                   | 800       | G          |

TABLE A2.2. (continued)

| Subzone | Sample # | Stocking status (ha) |    | NSR         |       | Stems per hectare |      | Treatment | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|----|-------------|-------|-------------------|------|-----------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR | Well-spaced | Total | Well-spaced       | SR   |           |        | Slope                | Elev. (m) | Site class |
| SBSb    | 60       | 33                   | 0  | 663         | 2694  | 0                 | 0    | —         | S      | 12                   | 900       | G          |
|         | 61       | 0                    | 8  | 0           | 0     | 1099              | 8020 | —         | NW     | 0                    | 900       | M          |
|         | 62       | 38                   | 0  | 205         | 2600  | 0                 | 0    | G BLOCK   | SE     | 10                   | 686       | M          |
|         | 63       | 49                   | 0  | 642         | 2225  | 0                 | 0    | —         | S      | 5                    | 1061      | M          |
|         | 64       | 32                   | 9  | 185         | 874   | 1133              | 4200 | —         | S      | 15                   | 1000      | M          |
|         | 65       | 0                    | 3  | 0           | 0     | 1600              | 8733 | —         | SE     | 50                   | 1061      | M          |
|         | 66       | 91                   | 0  | 693         | 2926  | 0                 | 0    | MCHAIN    | E      | 5                    | 1038      | M          |
|         | 67       | 14                   | 0  | 661         | 2138  | 0                 | 0    | —         | S      | 0                    | 1175      | G          |
|         | 68       | 0                    | 3  | 0           | 0     | 1160              | 6400 | BPILE     | SW     | 5                    | 1060      | M          |
|         | 69       | 61                   | 13 | 433         | 2288  | 1000              | 3588 | MCHAIN    | SE     | 5                    | 1060      | G          |
|         | 70       | 5                    | 0  | 300         | 2600  | 0                 | 0    | —         | S      | 10                   | 720       | M          |
|         | 71       | 0                    | 29 | 0           | 0     | 700               | 2500 | BPILE     | F      | 0                    | 1067      | M          |
|         | 72       | 0                    | 30 | 0           | 0     | 860               | 1530 | —         | S      | 5                    | 1100      | G          |
|         | 73       | 0                    | 81 | 0           | 0     | 1011              | 6011 | —         | F      | 0                    | 1067      | M          |
|         | 74       | 0                    | 32 | 0           | 0     | 856               | 4700 | —         | V      | 10                   | 1145      | M          |
|         | 75       | 0                    | 56 | 0           | 0     | 700               | 2000 | GROAD     | F      | 10                   | 1127      | M          |
|         | 76       | 0                    | 19 | 0           | 0     | 870               | 2500 | —         | V      | 15                   | 975       | G          |
|         | 77       | 0                    | 37 | 0           | 0     | 1010              | 4600 | —         | NW     | 5                    | 1067      | G          |
|         | 78       | 0                    | 51 | 0           | 0     | 969               | 5261 | —         | F      | 5                    | 1067      | G          |
|         | 79       | 0                    | 74 | 0           | 0     | 1000              | 1000 | —         | S      | 5                    | 975       | G          |
|         | 80       | 54                   | 0  | 578         | 3015  | 0                 | 0    | —         | F      | 0                    | 1067      | M          |
|         | 81       | 0                    | 54 | 0           | 0     | 733               | 4066 | —         | F      | 0                    | 1067      | M          |
|         | 82       | 0                    | 51 | 0           | 0     | 1037              | 6733 | —         | F      | 0                    | 1067      | M          |
|         | 83       | 0                    | 33 | 0           | 0     | 1800              | 5000 | GROAD     | SE     | 10                   | 1067      | M          |
|         | 84       | 0                    | 62 | 0           | 0     | 1320              | 3560 | GROAD     | S      | 25                   | 1006      | M          |
|         | 85       | 0                    | 6  | 0           | 0     | 983               | 3433 | GROAD     | V      | 10                   | 1100      | M          |

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin (continued)

| Subzone | Sample # | Stocking status (ha) |     | Stems per hectare |     |       | Treatment     | Aspect | Site characteristics |           |            |
|---------|----------|----------------------|-----|-------------------|-----|-------|---------------|--------|----------------------|-----------|------------|
|         |          | NSR                  | SR  | Well-spaced       | NSR | Total |               |        | Slope                | Elev. (m) | Site class |
| SBSb    | 86       | 0                    | 54  | 0                 | 0   | 3000  | —             | V      | 10                   | 1100      | M          |
|         | 87       | 0                    | 22  | 0                 | 0   | 4388  | —             | NE     | 5                    | 1290      | M          |
|         | 88       | 0                    | 58  | 0                 | 0   | 1800  | GROAD         | S      | 10                   | 1067      | M          |
|         | 89       | 0                    | 20  | 0                 | 0   | 1200  | GROAD         | S      | 5                    | 1057      | M          |
|         | 90       | 0                    | 50  | 0                 | 0   | 820   | GROAD         | S      | 5                    | 1300      | M          |
|         | 91       | 0                    | 45  | 0                 | 0   | 1500  | GROAD         | S      | 5                    | 1200      | M          |
|         | 92       | 0                    | 32  | 0                 | 0   | 1012  | GROAD         | s      | 5                    | 1250      | M          |
|         | 93       | 0                    | 19  | 0                 | 0   | 900   | GROAD         | F      | 0                    | 1341      | G          |
|         | 94       | 0                    | 78  | 0                 | 0   | 1029  | GROAD         | S      | 20                   | 1250      | M          |
|         | 95       | 0                    | 28  | 0                 | 0   | 817   | GROAD         | V      | 15                   | 1250      | G          |
|         | 96       | 0                    | 13  | 0                 | 0   | 733   | GROAD         | V      | 5                    | 1280      | P          |
|         | 97       | 0                    | 23  | 0                 | 0   | 588   | GROAD         | NW     | 15                   | 1341      | G          |
|         | 98       | 0                    | 91  | 0                 | 0   | 753   | GBLOCK, MPILE | SW     | 3                    | 1128      | M          |
|         | 99       | 0                    | 60  | 0                 | 0   | 750   | GROAD         | N      | 5                    | 1250      | M          |
|         | 100      | 0                    | 33  | 0                 | 0   | 1089  | GROAD         | N      | 10                   | 1250      | G          |
|         | 101      | 0                    | 72  | 0                 | 0   | 890   | —             | S      | 20                   | 1100      | M          |
|         | 102      | 0                    | 54  | 0                 | 0   | 840   | —             | S      | 30                   | 1115      | M          |
|         | 103      | 0                    | 107 | 0                 | 0   | 832   | GROAD         | V      | 5                    | 1380      | M          |
|         | 104      | 0                    | 34  | 0                 | 0   | 800   | GROAD         | S      | 5                    | 1250      | P          |
|         | 105      | 0                    | 43  | 0                 | 0   | 700   | GROAD         | S      | 10                   | 1300      | M          |
|         | 106      | 0                    | 22  | 0                 | 0   | 1053  | GTRAIL, GROAD | V      | 15                   | 1070      | M          |
|         | 107      | 0                    | 54  | 0                 | 0   | 1100  | —             | S      | 30                   | 1075      | M          |
|         | 108      | 0                    | 50  | 0                 | 0   | 1156  | —             | V      | 10                   | 1160      | M          |
|         | 109      | 0                    | 59  | 0                 | 0   | 1488  | —             | N      | 10                   | 1150      | M          |
|         | 110      | 0                    | 72  | 0                 | 0   | 850   | —             | V      | 10                   | 1175      | M          |
|         | 111      | 0                    | 13  | 0                 | 0   | 1100  | —             | V      | 15                   | 1070      | M          |

TABLE A2.2. (continued)

| Subzone | Sample # | Stocking status (ha) |     | Stems per hectare |      | Treatment | Aspect          | Site characteristics |           |            |      |   |
|---------|----------|----------------------|-----|-------------------|------|-----------|-----------------|----------------------|-----------|------------|------|---|
|         |          | NSR                  | SR  | Well-spaced       | NSR  |           |                 | Slope                | Elev. (m) | Site class |      |   |
| S8Sb    | 112      | 0                    | 27  | 0                 | 0    | 1000      | 1000            | —                    | V         | 10         | 1125 | M |
|         | 113      | 0                    | 44  | 0                 | 0    | 1429      | 2300            | —                    | N         | 20         | 1045 | M |
|         | 114      | 0                    | 46  | 0                 | 0    | 880       | 1975            | MTRAIL, GROAD        | F         | 0          | 1151 | M |
|         | 115      | 0                    | 74  | 0                 | 0    | 1000      | 1372            | —                    | V         | 10         | 1160 | M |
|         | 116      | 0                    | 64  | 0                 | 0    | 900       | 10,820          | GROAD                | W         | 5          | 1220 | M |
|         | 117      | 0                    | 43  | 0                 | 0    | 900       | 15,000          | GROAD                | F         | 0          | 1220 | M |
|         | 118      | 0                    | 27  | 0                 | 0    | 1064      | 5271            | GROAD                | M         | 5          | 1220 | M |
|         | 119      | 0                    | 82  | 0                 | 0    | 705       | 2857            | GROAD                | V         | 10         | 1250 | G |
|         | 120      | 0                    | 34  | 0                 | 0    | 1400      | 4000            | —                    | v         | 5          | 1067 | P |
|         | 121      | 0                    | 179 | 0                 | 0    | 1400      | 6000            | —                    | S         | 20         | 1067 | M |
|         | 122      | 0                    | 67  | 0                 | 0    | 1200      | 4000            | —                    | S         | 15         | 1067 | M |
|         | 123      | 0                    | 59  | 0                 | 0    | 1200      | 4000            | —                    | S         | 10         | 1067 | M |
|         | 124      | 0                    | 42  | 0                 | 0    | 1116      | 3653            | GROAD                | V         | 10         | 1098 | M |
|         | 125      | 0                    | 7   | 0                 | 0    | 1200      | 5371            | GROAD                | S         | 5          | 1098 | M |
|         | 126      | 0                    | 40  | 0                 | 0    | 1800      | 4000            | GROAD                | V         | 10         | 1250 | M |
|         | 127      | 0                    | 14  | 0                 | 0    | 1800      | 2000            | GROAD                | V         | 15         | 1098 | M |
|         | 128      | 0                    | 69  | 0                 | 0    | 1800      | 5000            | —                    | S         | 5          | 1067 | M |
|         | 129      | 0                    | 63  | 0                 | 0    | 1800      | 5000            | —                    | S         | 5          | 1067 | M |
|         | 130      | 0                    | 104 | 0                 | 0    | 1800      | 6000            | —                    | S         | 5          | 1067 | M |
|         | 131      | 45                   | 0   | 400               | 749  | 0         | 0               | GROAD                | S         | 10         | 1098 | M |
| 132     | 0        | 84                   | 0   | 0                 | 1000 | 2158      | GROAD           | NW                   | 5         | 1130       | M    |   |
| 133     | 0        | 22                   | 0   | 0                 | 964  | 1845      | —               | S                    | 30        | 1372       | G    |   |
| 134     | 0        | 77                   | 0   | 0                 | 718  | 4918      | GROAD           | S                    | 5         | 980        | M    |   |
| 135     | 0        | 11                   | 0   | 0                 | 867  | 4717      | GTRAILS, GROADS | N                    | 0         | 1220       | M    |   |
| 136     | 0        | 22                   | 0   | 0                 | 952  | 1895      | —               | S                    | 30        | 1372       | G    |   |
| 137     | 0        | 33                   | 0   | 0                 | 1173 | 5453      | GROAD           | V                    | 0         | 1372       | P    |   |

TABLE A2.2. Stocking and site characteristics of naturally regenerated lodgepole pine in openings in the Chilcotin (continued)

| Subzone | Sample # | Stocking status (ha) |    | NSR         |       | Stems per hectare |        | Treatment     | Aspect | Slope | Site characteristics |            |
|---------|----------|----------------------|----|-------------|-------|-------------------|--------|---------------|--------|-------|----------------------|------------|
|         |          | NSR                  | SR | Well-spaced | Total | Well-spaced       | Total  |               |        |       | Elev. (m)            | Site class |
| SBSb    | 138      | 0                    | 38 | 0           | 0     | 1146              | 5262   | GROAD         | V      | 5     | 1340                 | P          |
|         | 139      | 0                    | 79 | 0           | 0     | 1041              | 5570   | GROAD         | N      | 5     | 1189                 | M          |
|         | 140      | 0                    | 41 | 0           | 0     | 780               | 3140   | GROAD         | V      | 2     | 1159                 | M          |
|         | 141      | 0                    | 50 | 0           | 0     | 800               | 8493   | GROAD         | V      | 5     | 1159                 | M          |
|         | 142      | 0                    | 36 | 0           | 0     | 810               | 17,160 | GROAD         | V      | 5     | 1159                 | M          |
|         | 143      | 0                    | 55 | 0           | 0     | 792               | 3167   | GROAD         | S      | 5     | 1143                 | M          |
|         | 144      | 0                    | 31 | 0           | 0     | 810               | 3320   | GROAD         | V      | 5     | 1159                 | M          |
|         | 145      | 0                    | 53 | 0           | 0     | 748               | 1148   | —             | S      | 15    | 1070                 | M          |
|         | 146      | 0                    | 36 | 0           | 0     | 511               | 900    | GTRAIL, GROAD | S      | 15    | 1070                 | P          |
|         | 147      | 0                    | 27 | 0           | 0     | 764               | 2936   | GTRAIL, GROAD | V      | 10    | 1095                 | M          |
|         | 148      | 0                    | 30 | 0           | 0     | 760               | 1495   | GTRAIL, GROAD | V      | 10    | 1045                 | M          |
|         | 149      | 0                    | 38 | 0           | 0     | 636               | 2276   | GTRAIL, GROAD | V      | 10    | 1090                 | M          |
|         | 150      | 0                    | 17 | 0           | 0     | 938               | 2800   | GTRAIL, GROAD | V      | 10    | 1075                 | M          |
|         | 151      | 0                    | 17 | 0           | 0     | 820               | 2500   | GTRAIL, GROAD | V      | 10    | 1067                 | M          |
|         | 152      | 40                   | 34 | 370         | 1518  | 753               | 3383   | GTRAIL, GROAD | V      | 10    | 1105                 | M          |
|         | 153      | 0                    | 34 | 0           | 0     | 840               | 1200   | —             | V      | 10    | 1170                 | M          |
|         | 154      | 72                   | 0  | 1040        | 2200  | 0                 | 0      | —             | V      | 10    | 1050                 | M          |
|         | 155      | 0                    | 41 | 0           | 0     | 1380              | 1420   | —             | V      | 10    | 1060                 | M          |
|         | 156      | 26                   | 0  | 690         | 1550  | 0                 | 0      | —             | V      | 10    | 1055                 | M          |
|         | 157      | 0                    | 53 | 0           | 0     | 2067              | 4943   | —             | V      | 10    | 1097                 | M          |
|         | 158      | 0                    | 31 | 0           | 0     | 1104              | 2038   | —             | V      | 10    | 1164                 | M          |
|         | 159      | 0                    | 57 | 0           | 0     | 580               | 1825   | —             | V      | 10    | 1150                 | M          |
|         | 160      | 0                    | 53 | 0           | 0     | 770               | 3804   | —             | V      | 15    | 1125                 | M          |
|         | 161      | 0                    | 9  | 0           | 0     | 850               | 1667   | —             | SW     | 7     | 1069                 | M          |
|         | 162      | 0                    | 23 | 0           | 0     | 1098              | 2096   | —             | V      | 20    | 1372                 | G          |
|         | 163      | 0                    | 19 | 0           | 0     | 1344              | 2704   | —             | V      | 20    | 1372                 | G          |

TABLE A2.2. (concluded)

| Subzone | Sample # | Stocking status (ha) |     | NSR         |       | Stems per hectare |        | SR     | Treatment             | Aspect | Site characteristics |           |            |  |
|---------|----------|----------------------|-----|-------------|-------|-------------------|--------|--------|-----------------------|--------|----------------------|-----------|------------|--|
|         |          | NSR                  | SR  | Well-spaced | Total | Well-spaced       | Total  |        |                       |        | Slope                | Elev. (m) | Site class |  |
| SBSb    | 164      | 0                    | 47  | 0           | 0     | 767               | 1844   |        | —                     | N      | 5                    | 1200      | M          |  |
|         | 165      | 50                   | 0   | 411         | 821   | 0                 | 0      |        | —                     | NW     | 10                   | 1300      | G          |  |
|         | 166      | 0                    | 93  | 0           | 0     | 888               | 12,825 |        | —                     | S      | 7                    | 920       | M          |  |
|         | 167      | 81                   | 18  | 555         | 1145  | 1086              | 2914   |        | MSHARK, MPILE, MTRAIL | N      | 10                   | 1067      | G          |  |
|         | 168      | 0                    | 99  | 0           | 0     | 764               | 5200   |        | MCHAIN                | N      | 10                   | 1067      | G          |  |
|         |          |                      | 84  |             |       | 601               | 2315   |        |                       |        |                      |           |            |  |
|         | 169      | 0                    | 32  | 0           | 0     | 797               | 10,161 |        | MCHAIN                | N      | 10                   | 1067      | G          |  |
|         |          |                      | 55  |             |       | 762               | 7390   |        |                       |        |                      |           |            |  |
|         | 170      | 0                    | 15  | 0           | 0     | 662               | 2400   |        | MCHAIN, GROAD         | N      | 10                   | 1067      | G          |  |
|         |          |                      | 37  |             |       | 610               | 3653   |        |                       |        |                      |           |            |  |
|         | 171      | 0                    | 25  | 0           | 0     | 1011              | 2937   |        | MSHARK                | S      | 6                    | 910       | M          |  |
|         | 172      | 0                    | 40  | 0           | 0     | 652               | 2504   |        | MCHAIN                | E      | 10                   | 1006      | M          |  |
|         | 173      | 0                    | 44  | 0           | 0     | 677               | 5138   |        | MCHAIN                | SE     | 10                   | 1006      | M          |  |
|         | 174      | 0                    | 46  | 0           | 0     | 804               | 3304   |        | —                     | F      | 0                    | 915       | M          |  |
|         | 175      | 0                    | 30  | 0           | 0     | 961               | 3122   |        | MMACH                 | F      | 0                    | 915       | M          |  |
|         | 176      | 0                    | 44  | 0           | 0     | 834               | 7600   |        | MCHAIN                | S      | 5                    | 980       | M          |  |
|         | 177      | 0                    | 43  | 0           | 0     | 896               | 12,678 |        | MCHAIN, GROAD         | SE     | 5                    | 980       | M          |  |
|         | 178      | 0                    | 42  | 0           | 0     | 866               | 3906   |        | GROAD                 | V      | 2                    | 900       | M          |  |
|         | 179      | 0                    | 63  | 0           | 0     | 900               | 4885   |        | GROAD                 | SE     | 15                   | 976       | M          |  |
|         | 180      | 0                    | 130 | 0           | 0     | 952               | 6420   |        | MCHAIN                | S      | 12                   | 1015      | M          |  |
|         | 181      | 0                    | 67  | 0           | 0     | 797               | 8297   |        | MCHAIN                | V      | 10                   | 915       | M          |  |
|         | 182      | 0                    | 63  | 0           | 0     | 708               | 4790   |        | MCHAIN                | V      | 10                   | 915       | M          |  |
|         | 183      | 0                    | 50  | 0           | 0     | 643               | 3139   |        | —                     | SE     | 13                   | 1067      | M          |  |
|         | 184      | 0                    | 24  | 0           | 0     | 1193              | 3526   |        | —                     | N      | 7                    | 1200      | P          |  |
| 185     | 0        | 145                  | 0   | 0           | 872   | 5136              |        | MCHAIN | S                     | 15     | 915                  | M         |            |  |
| 186     | 0        | 62                   | 0   | 0           | 1061  | 4794              |        | MCHAIN | S                     | 8      | 1021                 | G         |            |  |
| 187     | 0        | 25                   | 0   | 0           | 978   | 3778              |        | GROAD  | S                     | 0      | 1000                 | M         |            |  |
| 188     | 74       | 81                   | 225 | 1000        | 966   | 5634              |        | —      | W                     | 5      | 1219                 | P         |            |  |